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Monitoring of Foredunes on Padre Island, Texas

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by
B.E. Dahl and J.P. Goen

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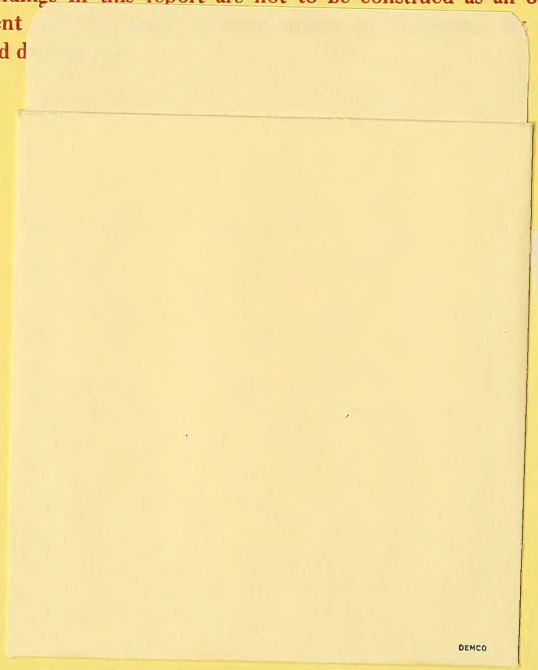

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This study was conducted to continue monitoring foredunes formed from grass plantings made during 1969 to 1973 on north Padre Island beaches. This report summarizes data obtained from elevational profiles and vegetative transects at four experimental foredune sections and one natural foredune section during 1975 and 1976. The beach and foredunes, a 655-foot (200 meters) cross section, gained 5.7 cubic yards (4.4 cubic meters) per linear foot of beach from August 1975 to August 1976. However, sand accumulation
(continued)

was not uniform; the north end of the study area gained no sand. Plantings, 50 feet (15 meters) wide seaward of existing foredunes proved to be an effective dune-widening technique. This has provided a 125-foot (38 meters) dune base versus an 80-foot (24 meters) dune base from initial 100-foot-wide (30 meters) plantings.

Sand-trapping rates averaged 6.3 cubic yards (4.8 cubic meters) per linear foot per year on foredunes of experimental plantings versus 4.0 cubic yards (3.1 cubic meters) for the unplanted, natural area. However, accumulation rates for the last year were 4.1 cubic yards for planted foredunes versus 4.0 cubic yards for the natural foredune. Apparently, the natural area is sufficiently vegetated to accumulate sand as rapidly as planted areas, but it has taken 15 years to reach this trapping efficiency and without a recognizable dune line. Rate of lateral grass spread from initial plantings varied from 5.25 to 7.24 feet (1.6 to 2.2 meters) per year. Vegetation studies show little invasion of unplanted species into the planted foredunes. Landward of planted dunes, grass establishment is well ahead of the unplanted area. The unplanted area is more arid. Mean elevations for dune crests 89 months after planting were 19.2 feet (5.9 meters) mean sea level versus 8.6 feet (2.6 meters) for the unplanted area.

PREFACE

This report contains results of a 2-year survey to monitor rates of sand deposition, vegetation dynamics, beach erosion and accretion, and maintenance requirements of beach plantings made during the previous 5 years. It is published to assist coastal engineers in building and maintaining coastal foredunes which act as effective barriers against storm surge, and enhance the environmental quality and productivity in the coastal zone. The research was carried out under the coastal ecology research program of the U.S. Army Coastal Engineering Research Center (CERC).

The report was prepared by Bill E. Dahl, Professor of Range and Wildlife Management, and John P. Goen, Research Associate, Department of Range and Wildlife Management, Texas Technological University (TTU), Lubbock, Texas, under CERC Contract No. DACW72-75-C-0011.

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Dr. D.W. Woodard, formerly of CERC, was largely instrumental in initiating the project. A.K. Hurme and P. Knutson were the CERC contract monitors, under the general supervision of R.M. Yancey, Chief, Coastal Ecology Branch, Research Division.

Comments on this publication are invited.

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JOHN H. COUSINS
Colonel, Corps of Engineers
Commander and Director

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CONVERSION FACTORS, U.S. CUSTOMARY TO METRIC (SI)
UNITS OF MEASUREMENT

U.S. customary units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	by	To obtain
inches	25.4	millimeters
	2.54	centimeters
square inches	6.452	square centimeters
cubic inches	16.39	cubic centimeters
feet	30.39	centimeters
	0.3048	meters
square feet	0.0929	square meters
cubic feet	0.0283	cubic meters
yards	0.9144	meters
square yards	0.836	square meters
cubic yards	0.7646	cubic meters
miles	1.6093	kilometers
square miles	259.0	hectares
knots	1.8532	kilometers per hour
acres	0.4047	hectares
foot-pounds	1.3558	newton meters
millibars	1.0197×10^{-3}	kilograms per square centimeter
ounces	28.35	grams
pounds	453.6	grams
	0.4536	kilograms
ton, long	1.0160	metric tons
ton, short	0.9072	metric tons
degrees (angle)	0.1745	radians
Fahrenheit degrees	5/9	Celsius degrees or Kelvins[1]

[1]To obtain Celsius (C) temperature readings from Fahrenheit (F) readings, use formula: $C = (5/9)(F - 32)$.

To obtain Kelvin (K) readings, use formula: $K = (5/9)(F - 32) + 273.15$.

MONITORING OF FOREDUNES ON PADRE ISLAND, TEXAS

by

B.E. Dahl and *J.P. Goen*

I. INTRODUCTION

Flood damage from hurricanes is a major concern to inhabitants of the Texas gulf coast. Barrier islands, such as Padre Island, provide significant protection against high water through the damming effect of foredunes which characteristically form parallel to the beach. Where these foredunes have been lost, storm surge erosion moves sand inland from the beach onto lowland vegetation and into lagoons, and the sand accumulates on roads and in navigation channels adjacent to the islands. After severe flooding from Hurricane Carla in 1961, mainland residents requested restoration of these natural dams on Padre Island.

From 1968 to 1974 the Coastal Engineering Research Center (CERC) supported research to define propagation and transplanting techniques with beachgrass to construct and rehabilitate these coastal foredunes (Dahl, et al., 1975). The data collected included information on changes in dune dimension and beach topography, encroachment of indigenous flora, and comparisons with naturally occurring foredunes. During these studies, several foredunes were formed from test plantings on the north and south ends of Padre Island (Fig. 1). Upon completion of the initial contracts, CERC continued monitoring the foredunes formed from the grass planting on north Padre Island beaches to evaluate the long-term performance and effects of the foredunes. This report basically summarizes beach and foredune cross-sectional profile surveys and vegetative transects of four experimental foredune sections and one natural foredune section conducted during 1975 and 1976. The foredunes are within the boundaries of the Padre Island National Seashore.

II. STUDY AREA

Padre Island has a subtropical, semiarid climate, moderated by maritime tropical air from the Gulf of Mexico. The summer months are hot with little daily or weekly variation. Winter (December to February) is mild with a wide fluctuation in temperature; freezing temperatures are infrequent. Precipitation is irregular, both monthly and annually, with no sharply defined seasons. Within the last century, annual precipitation at Corpus Christi has ranged from 48.16 inches (1,222 millimeters) in 1888 to 5.38 inches (136 millimeters) in 1917. Excessive precipitation associated with

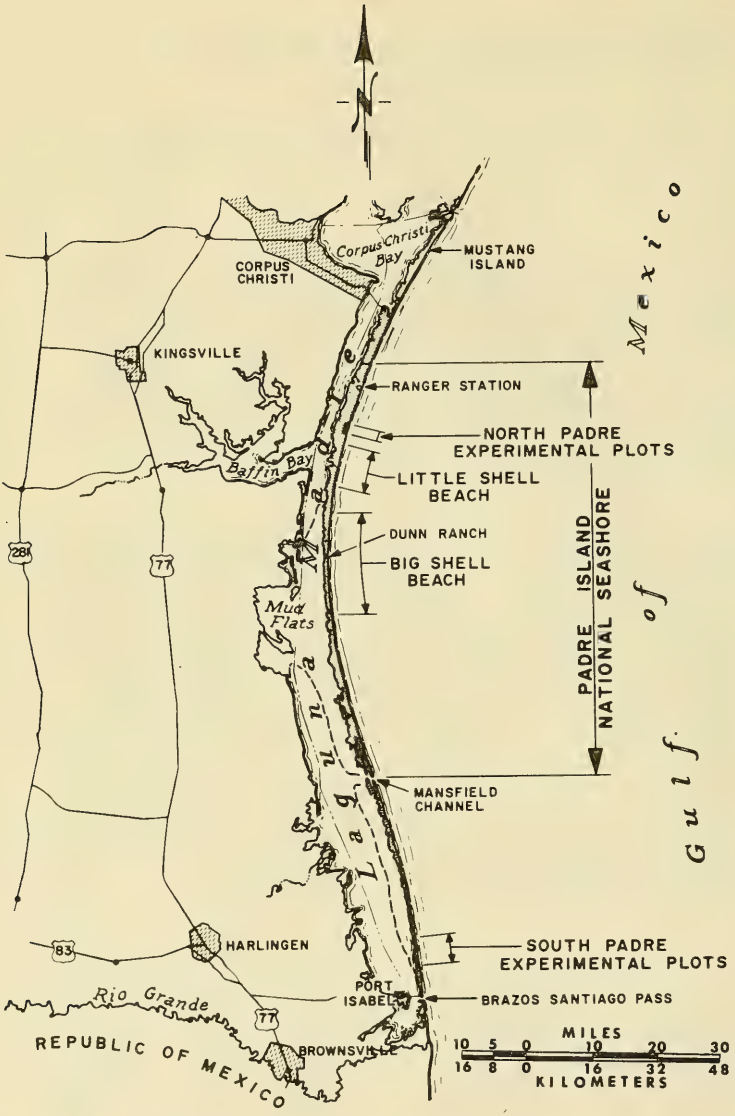


Figure 1. Map of Padre Island, Texas.

hurricanes, usually in late summer and early fall, biases the annual average upwards. Without this boost, the averages would be lower and more indicative of the stress associated with semiarid lands where droughts are frequent but irregular (Carr, 1966). Average temperature for Corpus Christi, the nearest station with longtime weather data is 71.7° Fahrenheit (21.7° Celsius); average precipitation is 26.72 inches (678 millimeters) (Department of Commerce, 1970).

Two principal wind regimes dominate the Texas coastal zone—persistent, southeasterly winds from March to September, and north-northeasterly winds from October to February (Behrens, Watson, and Mason, 1977). However, prevailing winds (disregarding wind-speed) are onshore 11 months of the year (Dahl, et al., 1975). Northerly winds are associated with frontal passages and are usually strong with concurrent precipitation. However, some northers are dry, building small dunes along the beach with each passage. Prevailing winds then transport this sand back to the foredunes.

The coastal topography of the mainland and adjacent to Padre Island is relatively flat with soils developed from Pleistocene and recent unconsolidated clastic sediments. The soils of Padre Island developed on recent marine and eolian soils. Sand particle size is dominantly fine to very fine sand. It is highly variable in salt content with varying amounts of shell and organic matter. The highest organic matter content from beach sands was 0.1 percent. Shell fragments were mostly less than 1 percent (Dahl, et al., 1975).

A schematic cross-sectional profile of north Padre Island and the dominant plants of major communities are shown in Figure 2. North Padre Island is predominantly grassland of midheight. Seacoast bluestem (*Schizachyrium scoparium* var. *littoralis*), seashore dropseed (*Sporobolus virginicus*), gulfdune paspalum (*Paspalum monostachyum*), and saltmeadow cordgrass (*Spartina patens*) are species that commonly occur from the foredune across the island.

The number of species on the shoreface of the dunes is limited, with sea oats (*Uniola paniculata*) the dominant sand-trapping plant. Other species capable of trapping or binding sand are saltmeadow cordgrass, seashore dropseed, bitter panicum (*Panicum amarum*), railroad vine (*Ipomoea pes-caprae*), and gulf croton (*Croton punctatus*). After dunes have been started by pioneer vegetation, forbs such as beach groundcherry (*Physalis viscosa*), beach evening primrose (*Oenothera drummondii*), and prairie senna (*Cassia fasciculata*) often become common.

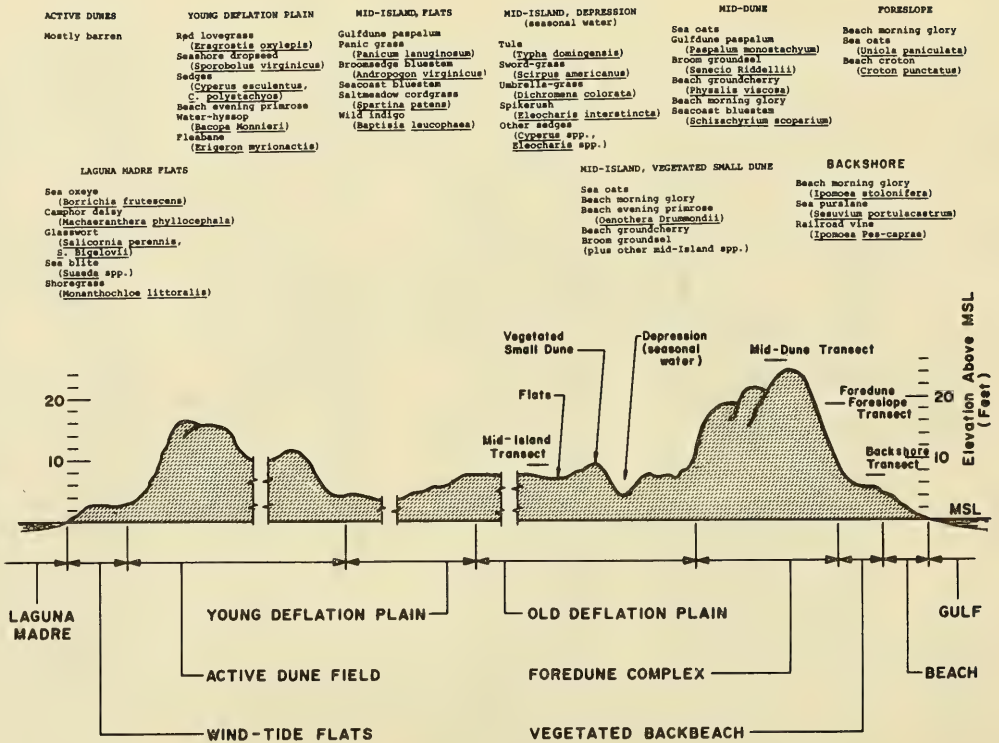


Figure 2. Schematic cross-sectional profile of north Padre Island and some dominant plants of major communities (vicinity of Ranger Station, Padre Island National Seashore).

Of particular interest to this study is the vegetation of the backshore and the foredune foreslope, and the natural succession of plants from a barren, hurricane-planed backshore to a continuous, mature foredune ridge. Sea purslane (*Sesuvium portulacastrum*), one of the first species to re-appear on the denuded backshore, is vegetatively dispersed by wave and wind action. Clumps of sea purslane trap sand, forming small dunes which rise only a few feet above the beach surface. Beach morning glory (*Ipomoea stolonifera*), railroad vine, gulf croton, sea oats, saltmeadow cordgrass, bitter panicum, and seashore dropseed are early colonizers (Dahl, et al., 1975).

Rhizomatic growth and tillering of these grasses, especially sea oats and bitter panicum, are stimulated by the accumulation of fresh sand continually blown inland from the shore. Windblown sand is trapped by exposed grass blades and eventually stabilized by the root and rhizome system. Fed by fresh beach sand blowing inland, the unconnected hummock dunes of sea oats, bitter panicum, saltmeadow cordgrass, and seashore dropseed continue growing and eventually interconnect, forming a dune ridge. New hummock dunes begin forming shoreward, and in this manner, the foredune grows toward the gulf. This shoreward growth eventually eliminates fresh sand accumulation on the rear of the dune ridge, and affords additional protection from wind and salt spray. Less salt-tolerant species and species not adapted to growing in accumulating sand then become established; e.g., seacoast bluestem, gulfdune paspalum, broom groundsel (*Senecio riddellii*), and beach groundcherry (Dahl, et al., 1975).

The time scale for these sequences is dependent on the intervals between storms, the severity of previous storm damage, the proximity of undamaged colonizing species, and the precipitation cycle. The area containing the present study plots was barren in 1937, but by 1948 a vegetated foredune ridge had appeared with a vegetated plain to the west. By 1967, after Hurricanes Carla and Beulah, the dune ridge was absent, and the area was again barren with a field of active sand dunes migrating west.

III. METHODS: EXPERIMENTAL PLOTS

1. Experimental Plots.

A summary of the experimental plots is given in Table 1 which corresponds with the study site map in Figure 3. These experimental plots and an unplanted naturally forming dune area are also included in Appendix A which shows exact measurements referenced to two surveyed base lines (east and west).

Table 1. Experimental planting sites on north Padre Island.

Description	Planting dates	Comments
1,200-foot sea oats (Twin Batteries)	Mar. 1969	Original plantings, three-fourths saltmeadow cordgrass and one-fourth sea oats. Percent survival: cordgrass, 14; sea oats, 46. Cattle grazing an early problem. Supplemental fill-in plantings of sea oats, cordgrass, and panicum (shoredune and bitter).
1,500-foot monthly plant-species comparisons	1969 to 1970	Test plantings in small blocks of bitter panicum, sea oats, saltmeadow cordgrass, and seashore dropseed; planted over 2 years. Survival: irregular; dune not uniform.
400-foot dune-width extension plot. Planted gulfward of south end of monthly plantings	Apr. 1973	3:1 mixture of bitter panicum to sea oats. Percent survival: panicum, 62; sea oats, 1.
1,100-foot bitter panicum	Feb. 1970	Bitter panicum alternated with sea oats seed. Percent survival: panicum, 17; sea oats, unsuccessful. Subsequent patchwork planting.
1,200-foot dune-width bitter panicum	Feb. 1972 and Apr. 1972	North half planted with bitter panicum; 76 percent survival. South half planted with sea oats but destroyed by jackrabbits. Replanted in April with bitter panicum; 17-percent survival.

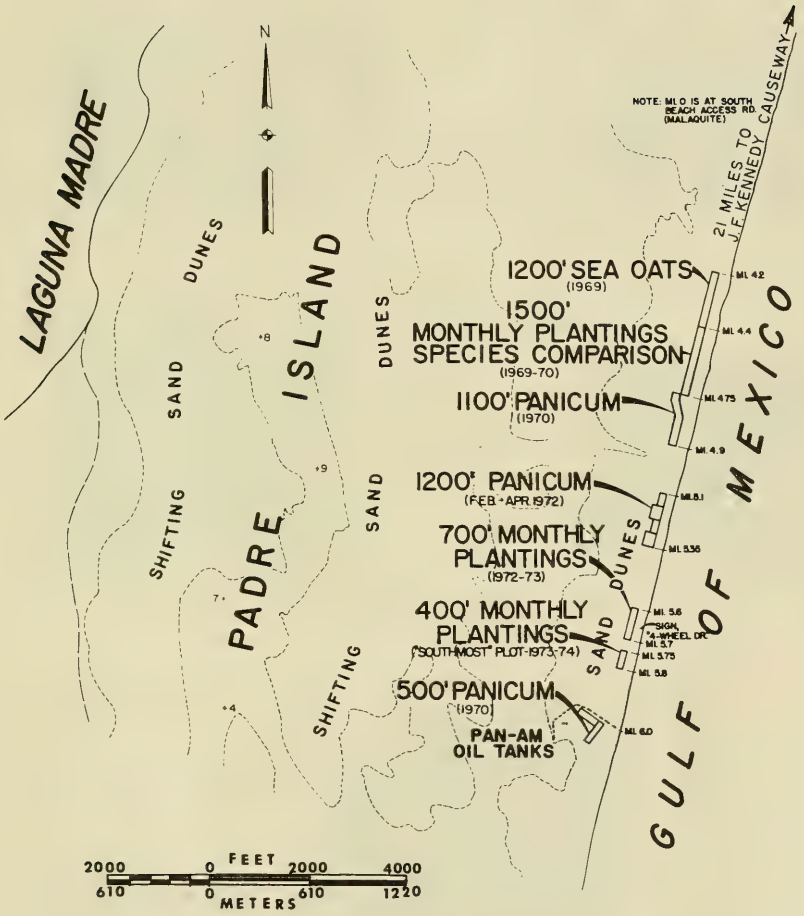


Figure 3. Location of north Padre Island experimental plantings (map courtesy of U.S. Army Engineer District, Galveston).

2. Methods and Procedures.

a. Elevational Surveys. Cross-sectional profile surveys for five experimental dune areas (Fig. 4) were conducted in March 1975, August 1975, March 1976, and August 1976. Foredune profiles were as follows:

(a) Unplanted natural dune area— eight profiles, 100 feet (30 meters) apart, from 100 feet in front of the natural dune area to 200 feet (61 meters) across the foredune area. Elevations were taken at 10-foot (3 meters) intervals (rod readings to the nearest 0.01 foot).

(b) 1,200-foot sea oats dune— 12 profiles, 100 feet apart, from 100 feet seaward of the grass extension of the dune to 190 feet (58 meters) across the dune.

(c) Dune-width extension dune— three profiles.

(d) 1,100-foot bitter panicum dune— 12 profiles, 90 feet (27 meters) apart.

(e) 1,200-foot bitter panicum dune— 12 profiles, 100 feet apart.

Cross-sectional beach profiles were as follows:

(a) Unplanted natural dune stations 3+00 and 6+00.

(b) BM "A1".

(c) 1,200-foot sea oats dune, stations 3+50 and 7+50.

(d) Dune-width extension dune, station 2+09.

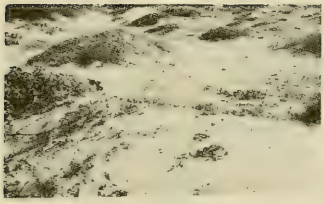
(e) 1,100-foot bitter panicum dune, stations 3+15 and 6+75.

(f) BM "Kenny".

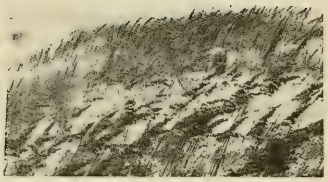
(g) 1,200-foot bitter panicum dune, stations 3+50 and 6+50.

Elevations were read at 20-foot (6 meters) intervals and keyed to the east base line.

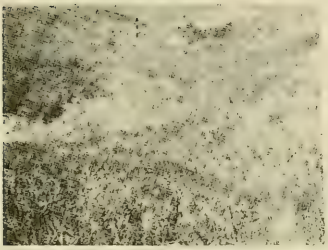
Two longitudinal surveys along the top of the dunes and parallel to the beach were made as follows for the 1,200-foot sea oats, 1,100-foot bitter panicum, and 1,200-foot bitter panicum dunes.



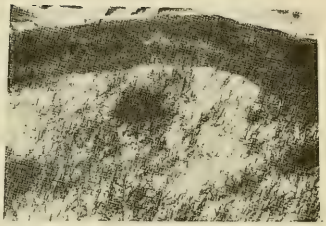
a. Unplanted natural area



b. 1,200-ft sea oats area



c. Dune-width extension area



d. 1,100-ft bitter panicum area

e. 1,200-ft bitter panicum area

Figure 4. Experimental foredunes.

One profile line was placed to coincide with the seaward crest of the foredunes. The other was 30 to 50 feet (9 to 15 meters) landward of the first profile line. For the 1,200-foot bitter panicum dune, a third line was placed at the landward edge of the 100-foot-wide plantings for the 300- to 600-foot (91 to 183 meters) and 900- to 1,200-foot (274 to 366 meters) segments. For the dune-width extension, the south 500 feet (122 meters) of the 1,500-foot (457 meters) monthly planting-species comprison foredune,longitudinal profiles were surveyed for both the seaward 50-foot width and the landward 50-foot width. Elevations were recorded with each abrupt change in topography. Distances were measured by tape to the nearest foot (0.3 meter).

b. Photos. Colored slides (35 millimeter) and black and white photos of the foredunes were taken at each profile survey. Eleven photo points for each of the five study areas are as follows:

(a) From 200 feet in front of the dune looking bayward at the dune.

(b) Three views from the north end of the dune looking south— along the gulf side, from the top of the dune, and along the bay side of the dune.

(c) Two views (bayward and gulfward) from the north end top of the dune.

(d) Three views from the south end looking north— along the gulf side, along the top, and along the bay side.

(e) Two views (gulfward and bayward) from the top of the south end.

c. Vegetation. In August 1975 and August 1976 vegetative transects were made in the five study areas. The following transects were placed paralleling the beach: a 60-plot transect on the seaward slope of the foredune, a 60-plot transect on the landward slope of the foredune, a 40-plot transect 25 feet (8 meters) landward of the dune, a 40-plot transect 125 feet (38 meters) landward of the dune, and a 40-plot transect 225 feet (69 meters) landward of the dune. A 3.70-foot-diameter (133 centimeters) circular plot with an area of 1 square meter was used. Frequency and cover data were recorded in each plot. Cover classes recorded were: 1, 0 to 1 percent; 2, 1 to 5 percent, 3, 5 to 25 percent; 4, 25 to 50 percent; 5, 50 to 75 percent; 6, 75 to 95 percent; 7, 95 to 99 percent; and 8, 99 to 100 percent (App. B). An importance value (IV) was computed by multiplying cover times frequency.

IV. RESULTS

1. Cross-Sectional and Longitudinal Profiles.

a. Total Sand Volume from Mean Sea Level Inland 655 feet (200 meters). From the past 2 years' surveys on Padre Island, sand volumes have been computed several ways to understand dynamics of sand accumulation and redistribution. First, consider total sand volume from mean sea level (MSL) inland through the part of the beach normally occupied by the foredunes. In this study, a 655-foot segment was used; the gulf side 355 feet (102 meters) was designated the beach segment, and from 355 to 655 feet was designated the foredune segment (Table 2; Figs. 5 to 10).

Two things appear to be happening based on these data. One, the north end of the study area, i.e., the unplanted natural dune and the 1,200-foot sea oats dune accumulated little sand in this 655-foot segment from August 1975 to August 1976. The middle of the area, the dune-width extension dune, and the 1,100-foot bitter panicum dune accumulated most. Sand accumulation for this 1-year period was 1.4, 0.2, 11.0, 8.9 and 7.0 cubic yards (1.1, 0.2, 8.4, 6.8, and 5.4 cubic meters) per linear foot of beach for the unplanted area, 1,200-foot sea oats, dune-width extension, 1,100-foot bitter panicum, and 1,200-foot bitter panicum areas, respectively.

Secondly, during the March 1975 survey, unusually high tides moved water all the way to the foot of the dunes several days in succession. Apparently, this high water washed considerable sand into the gulf from the 200 feet of beach nearest the gulf. This is clearly shown in Figures 6 to 10. However, after 5 months this sand was re-deposited on the beach, as shown in the figures, so it was not lost, just re-distributed.

For the beach segment (MSL to 335 feet), the north two study areas lost sand to the foredunes, but the south three had a net sand gain on both the beach and the foredune segments. Volume changes on the beach from August 1975 to August 1976 were -1.2, -2.8, 3.6, 3.1, and 1.8 cubic yards (-0.9, -2.1, 2.8, 2.4, and 1.4 cubic meters), respectively for the unplanted, 1,200-foot sea oats, dune-width extension, 1,100-foot bitter panicum, and 1,200-foot bitter panicum study areas. For the foredune segments of these areas, sand accumulations were 2.6, 3.0, 7.4, 5.9, and 5.2 cubic yards (2.0, 2.3, 5.7, 4.5, and 4.0 cubic meters) per linear foot of beach (Table 2).

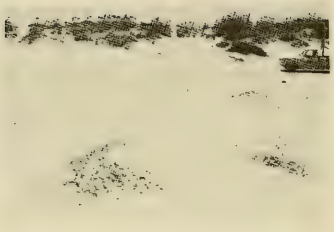
On the average, the beach and foredunes of this short section of north Padre Island gained 5.7 cubic yards (4.4 cubic meters) per linear foot of beach during this 12-month period. Although no segment lost sand, the stretch of beach from the south end

Table 2. Total sand volume for beach cross sections.

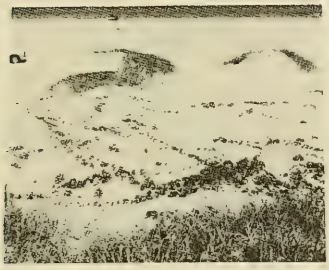
Location	Volume by survey date, yd^3 (m^3)			
	Mar. 1975	Aug. 1975	Mar. 1976	Aug. 1976
Beach segment (MSL to 355 ft)				
Unplanted area	40.1(30.7)	49.6(37.9)	48.1(36.8)	48.4(37.0)
1,200-ft sea oats	40.1(30.7)	49.2(37.6)	45.0(34.3)	46.4(35.5)
Dune-width extension	____[1]	48.0(36.7)	47.2(36.1)	51.6(39.5)
1,100-ft bitter panicum	40.2(30.7)	44.7(34.2)	45.5(34.8)	47.8(36.5)
1,200-ft bitter panicum	36.5(27.9)	42.5(32.5)	45.9(35.1)	44.3(33.9)
Avg.	39.2	46.8	46.3	47.7
Foredune segment (336 to 655 ft)				
Unplanted area	80.4(61.5)	81.4(62.2)	84.2(64.4)	84.0(64.2)
1,200-ft sea oats	87.6(67.0)	91.5(70.0)	93.1(71.2)	94.5(72.3)
Dune-width extension	____[1]	90.5(69.2)	89.3(68.3)	97.9(74.9)
1,100-ft bitter panicum	81.1(62.0)	82.9(63.4)	85.9(65.7)	88.8(67.9)
1,200-ft bitter panicum	82.7(63.2)	84.4(64.5)	83.6(63.9)	89.6(68.5)
Avg.	83.0	86.1	87.2	91.0
Total segment (MSL to 655 ft)				
Unplanted area	120.5(92.2)	131.0(100.1)	132.3(101.2)	132.4(101.2)
1,200-ft sea oats	127.7(97.7)	140.7(107.6)	138.1(105.6)	140.9(107.8)
Dune-width extension	____[1]	138.5(105.9)	136.5(104.4)	149.5(114.4)
1,100-ft bitter panicum	121.3(92.7)	127.7(97.6)	131.4(100.5)	136.6(104.4)
1,200-ft bitter panicum	119.2(91.1)	126.9(97.0)	129.5(99.0)	133.9(102.4)
Avg.	122.2	133.0	133.6	138.7

[1] Not surveyed in March 1975.

a. Unplanted natural area



b. 1,200-ft sea oats dune



c. Typical beach area gulfward of 1,200-ft bitter panicum dune

Figure 5. Foredune study segments.

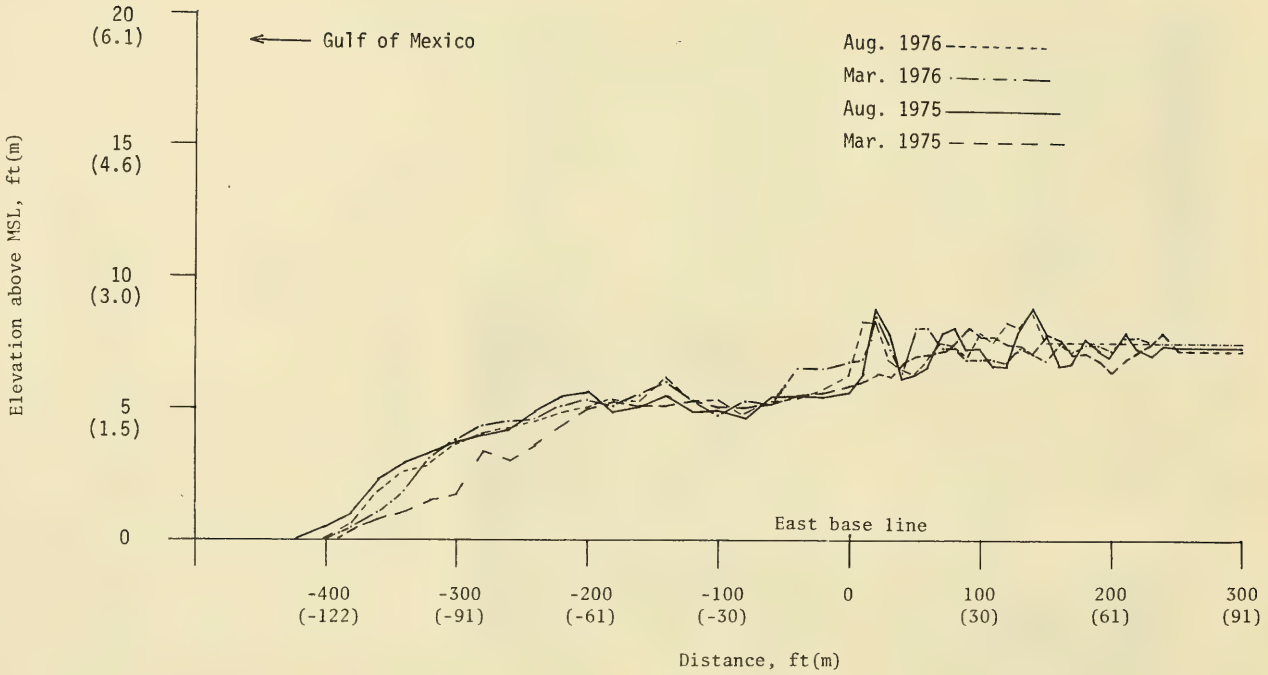


Figure 6. Cross-sectional beach and dune profiles for the unplanted natural dune area. Each is the mean of stations 3+00 and 6+00 profiles.

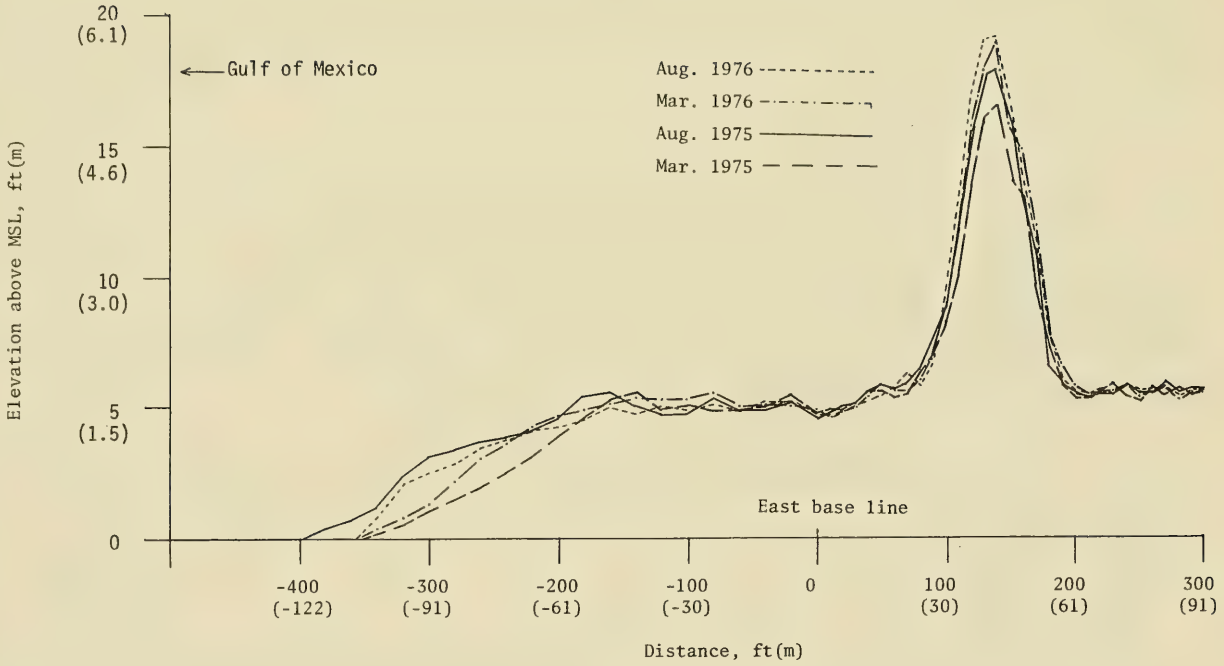


Figure 7. Cross-sectional beach and dune profiles for the 1,200-foot sea oats dune. Each is the mean of stations 3+50 and 7+50 profiles.

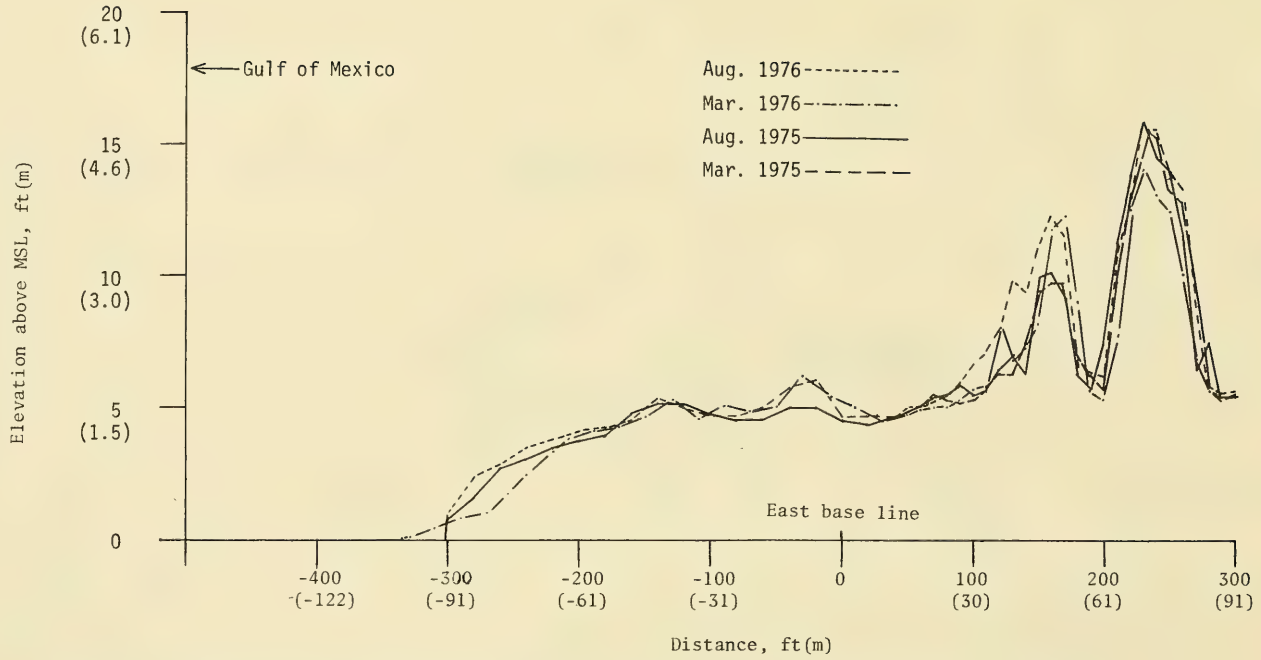


Figure 8. Cross-sectional beach and dune profiles for the dune-width extension dune. Each is a single profile.

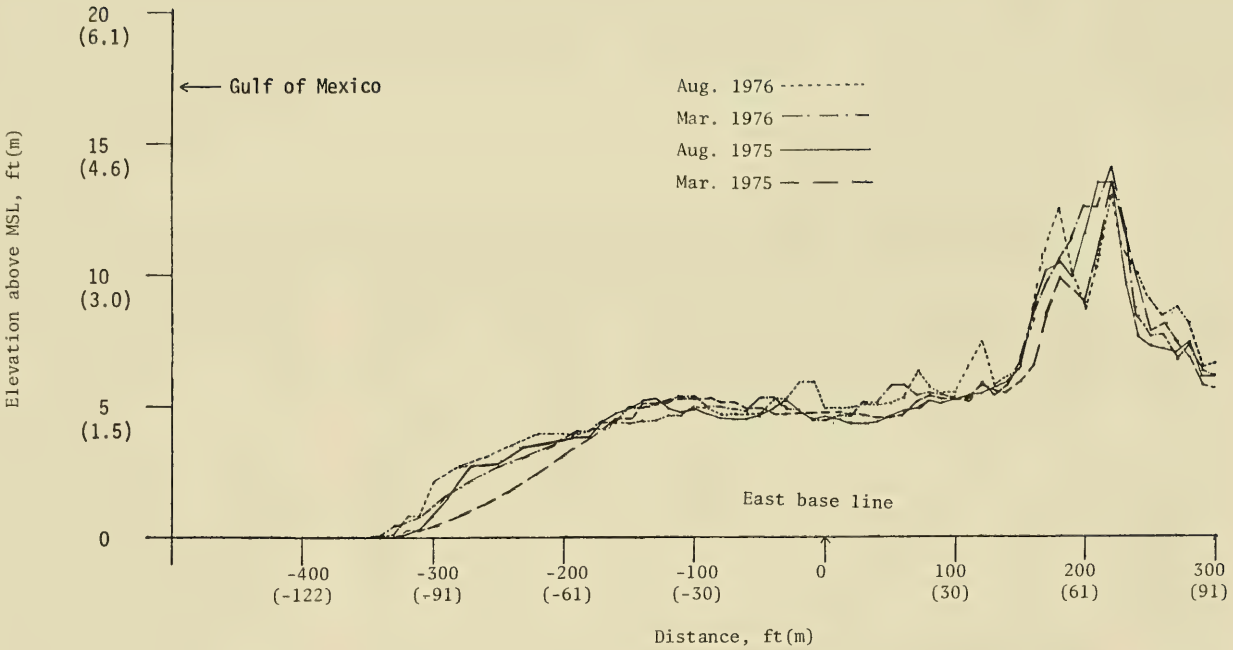


Figure 9. Cross-sectional beach and dune profiles for the 1,100-foot bitter panicum dune. Each is the mean of stations 3+15 and 6+75 profiles.

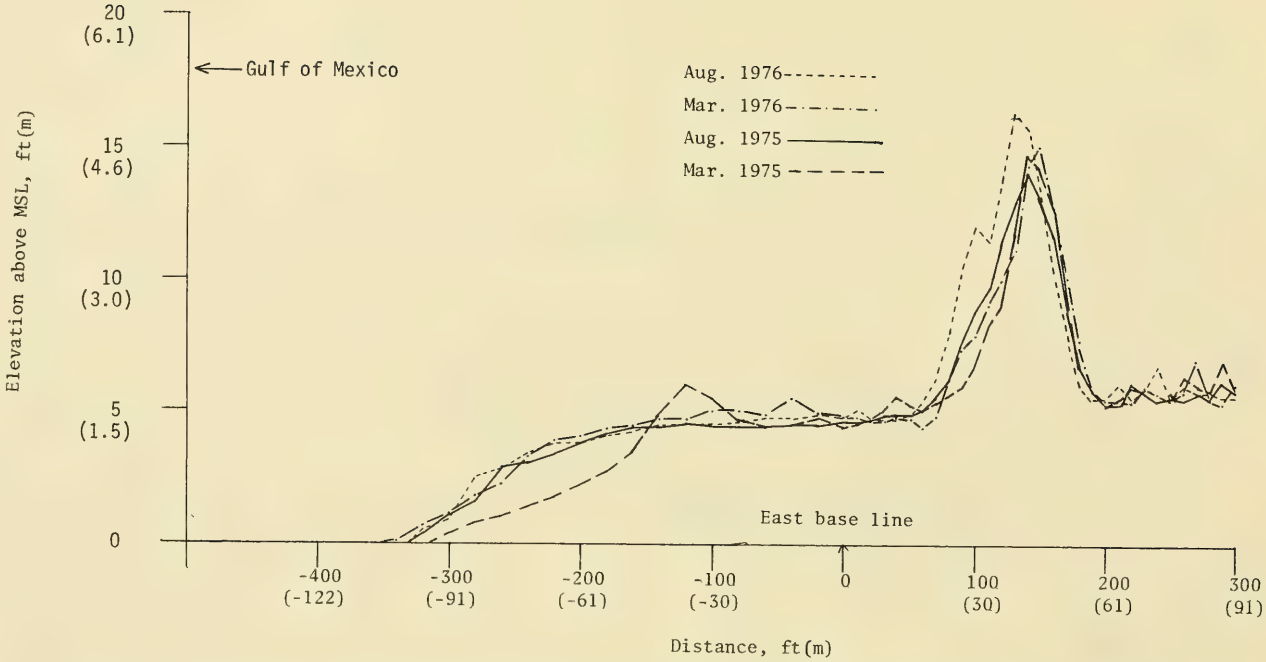


Figure 10. Cross-sectional beach and dune profiles for the 1,200-foot bitter panicum dune. Each is the mean of stations 3+50 and 6+50 profiles.

of the 1,200-foot sea oats dune to the north end of the 1,100-foot bitter panicum dune received the most sand during this study. This same pattern was also noted in an earlier study (Dahl, et al., 1975). However, the relative rates of sand accumulation may change from year to year along this stretch of beach.

b. Sand Volumes above Planting Elevation for 100-foot Segment in the Foredunes. Sand volumes were measured from early in 1970 in those areas immediately affected by the experimental dune plantings (Dahl, et al., 1975). For most surveys of the 100-foot cross sections, about 25 feet on either side of the plantings was measured. This measurement was continued through the 1976 surveys for comparison purposes. The values are tabulated in Table 3 and Figure 11. The dune-width extension plantings were not included in these measurements.

Although total sand in the entire beach system did not accrete on the 1,200-foot sea oats dune during 1975-76, modest increases influenced by the plantings did occur on this 100-foot segment. Accumulations above the 4-foot (1.2 meters) MSL planting elevation in August 1976 were three times those of a similar segment of unplanted beach. The younger bitter panicum plantings also had 2 to 2.5 times more sand in the planting locale than the unplanted area had (Table 3). Therefore, the plantings adequately confined the migrating beach sand to the planting area as intended.

c. Sand Volumes of 290-foot (88 meters) Segment of the Foredune. For a better evaluation of the role of artificial dune building through revegetation, it was necessary to study more than the 100-foot segment immediately over the plantings proper because the plantings influence sand accumulation for a much greater distance, particularly in front. Figures 12 to 17 and Tables 4 and 5 show the sand accumulation for a 290-foot segment. This distance includes the area of the 100-foot segment over the plantings. Basically, it extends 100 feet seaward of the current grass extension, and 190 feet landward. This 290 feet is far enough to reach beyond the influence of the plantings on sand accumulation in both directions.

Total sand accumulation in the unplanted area is well below that for the planted dunes (Table 4). However, for this larger segment of the beach system, the unplanted study area accumulated about as much sand from August 1975 to August 1976 as the planted study segments did (Table 6). This trend is expected to continue, at least until a major surge again denudes the area, for two major reasons. First, there is sufficient pioneer vegetation established in the unplanted area to trap all sand moving through the foredune area. The area has numerous "pimple" dunes that are accumulating sand but no continuous dunes of any kind yet

Table 3. Sand volumes accumulated above planting elevation for the immediate locale of the planting[1].

Location	Planting Elevation ft(m)	Volume by survey date, yd^3(m^3)											
		1970		1971		1972		1973	1974	1975		1976	
		May	Aug.	May	Aug.	Apr.	July	May	Mar.	Mar.	Aug.	Mar.	Aug.
Unplanted area	4.0 (1.2)								4.80 (3.7)	7.61 (5.8)	8.72 (6.7)	9.07 (6.9)	10.44 (8.0)
1,200-ft sea oats	4.0 (1.2)	2.1 (1.6)	2.7 (2.1)	9.1 (7.0)	11.1 (8.5)	16.7 (12.8)	16.0 (12.2)	20.0 (15.3)	21.3 (16.3)	28.4 (21.7)	31.7 (24.2)	32.9 (25.2)	33.8 (25.8)
1,100-ft bitter panicum	4.4 (1.3)				6.9 (5.3)	7.4 (5.7)	10.0 (7.6)	11.7 (8.9)	18.2 (13.9)	21.5 (16.4)	23.0 (17.6)	24.7 (18.9)	25.8 (19.7)
1,200-ft bitter panicum	5.2 (1.6)							3.0 (2.3)	8.5 (6.5)	15.4 (11.8)	17.6 (13.5)	18.1 (13.8)	21.7 (16.6)

[1]Planting width, 50 feet, surveyed distance, 100 feet.

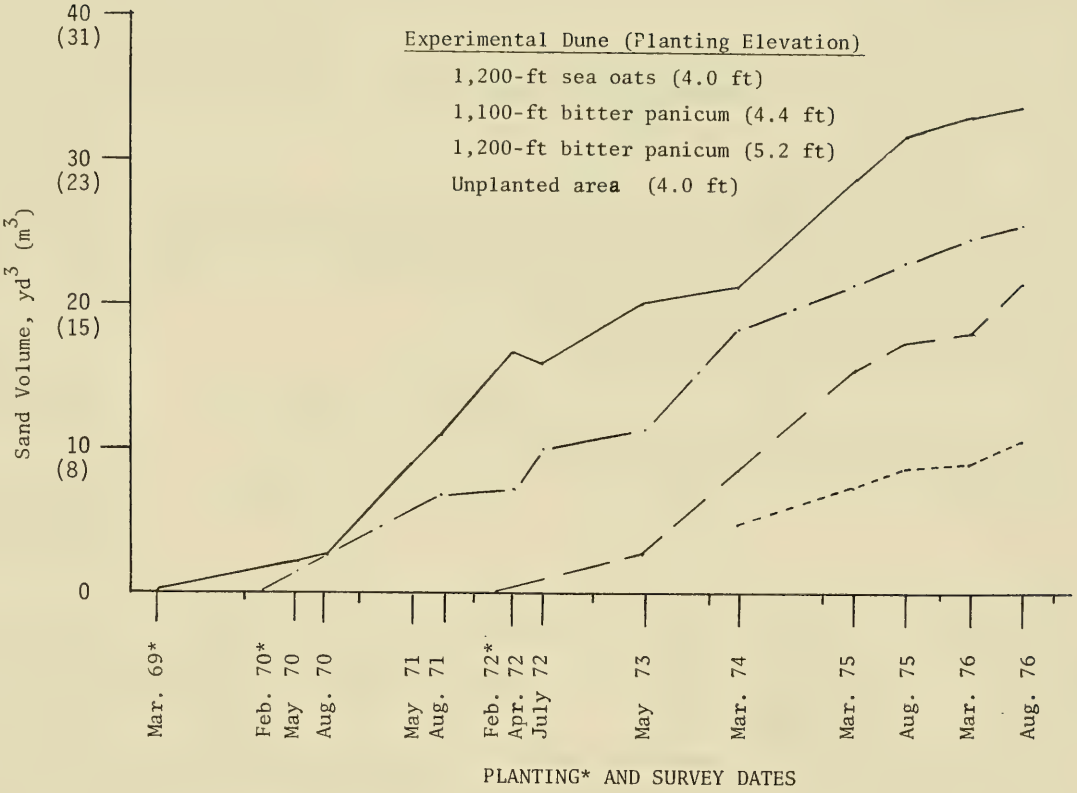


Figure 11. Sand volumes accumulated above planting elevation for four study dunes as determined from 100-foot-wide cross-section surveys over the planting.

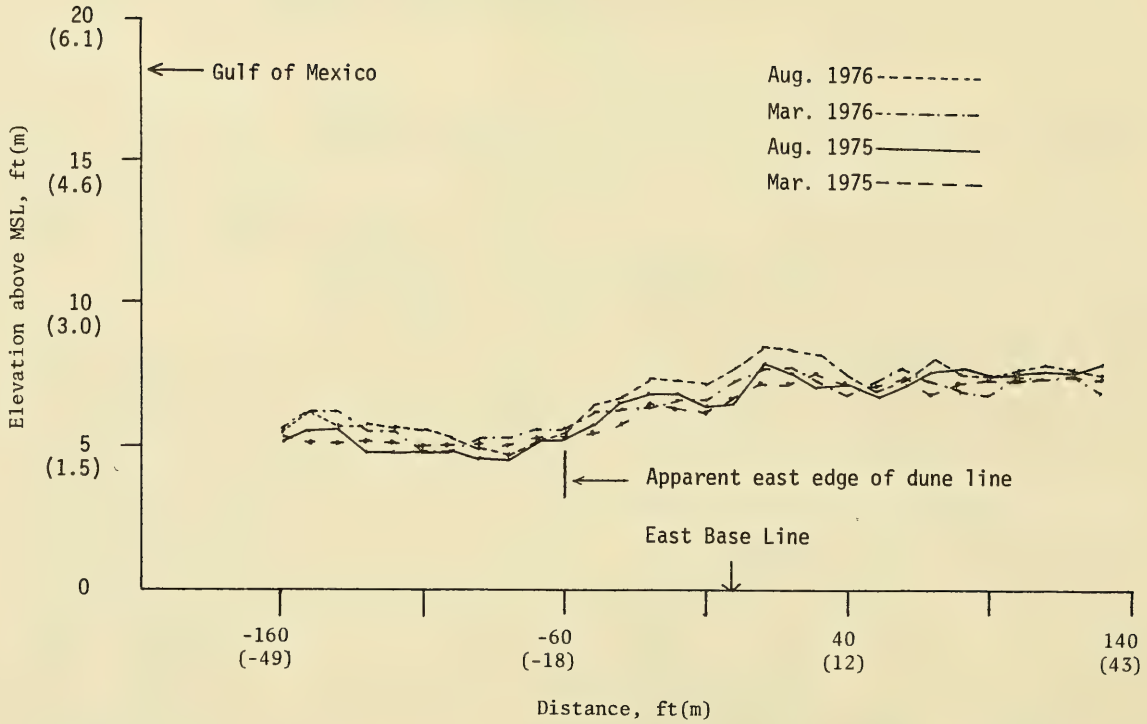


Figure 12. Mean cross-sectional profiles of the unplanted natural area. Profiles extend 290 feet across the foredunes. Each is the mean of eight profiles.

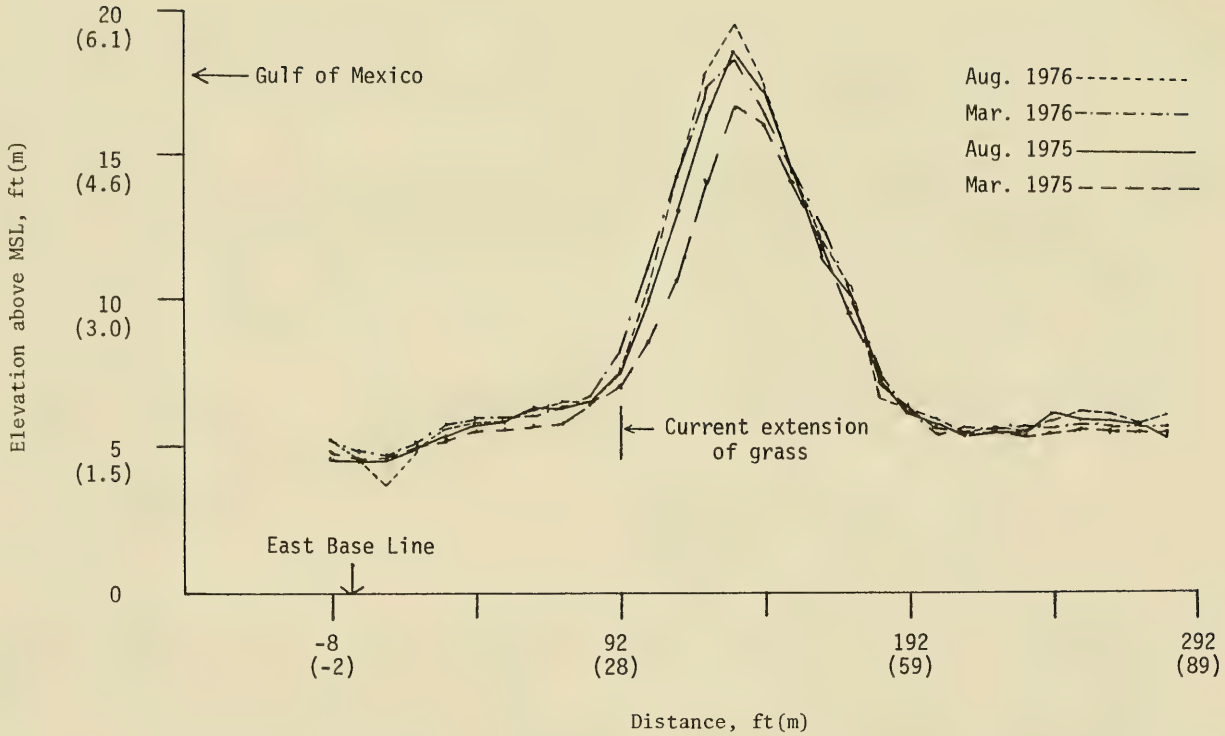


Figure 13. Mean cross-sectional profiles of the 1,200-foot sea oats dune. Profiles extend 290 feet across the foredunes. Each is the mean of 12 profiles.

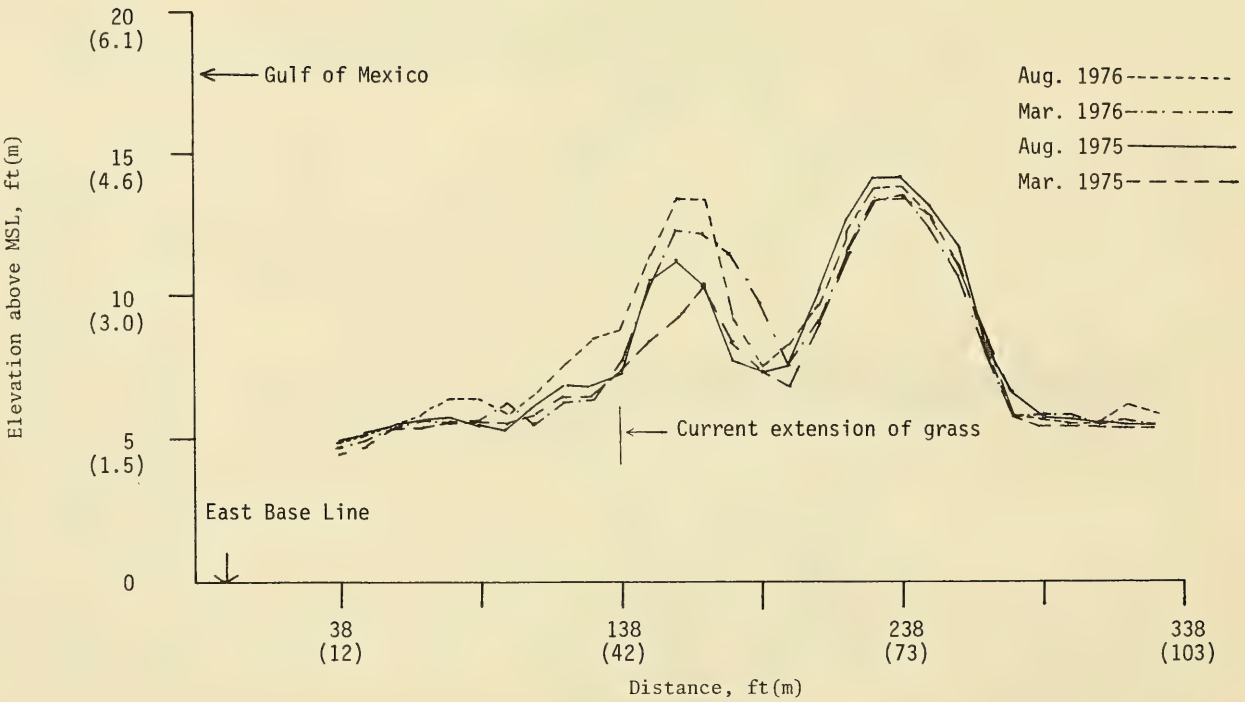


Figure 14. Mean cross-sectional profiles of the dune-width extension dune. Profiles extend 290 feet across the foredunes. Each is the mean of three profiles.

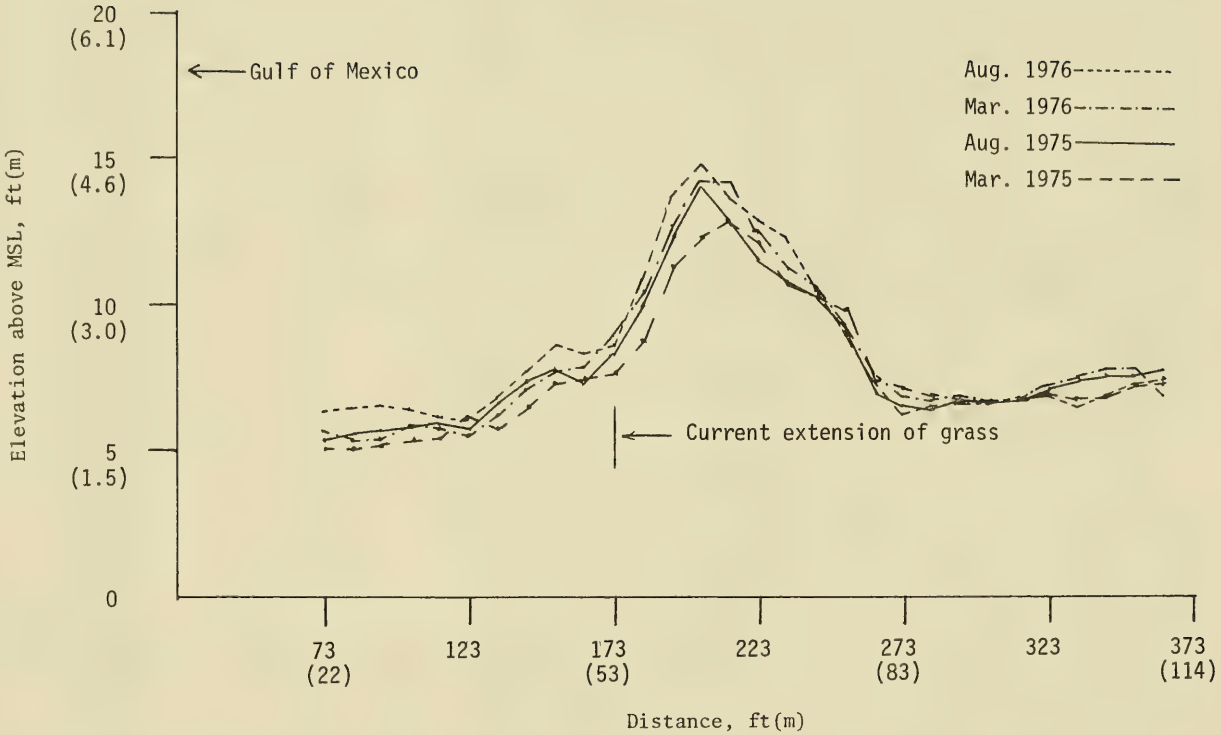


Figure 15. Mean cross-sectional profiles of the 1,100-foot bitter panicum dune. Profiles extend 290 feet across the foredunes. Each is the mean of 12 profiles.

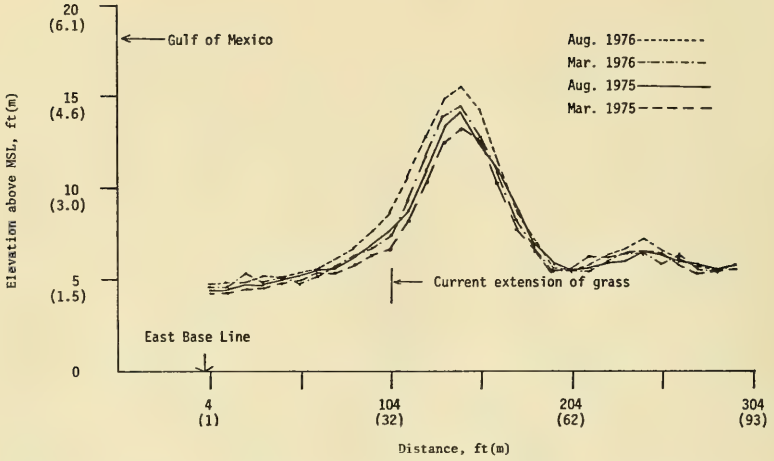


Figure 16. Mean cross-sectional profiles of the 1,200-foot bitter panicum dune. Profiles extend 290 feet across the foredunes. Each is the mean of 12 profiles.

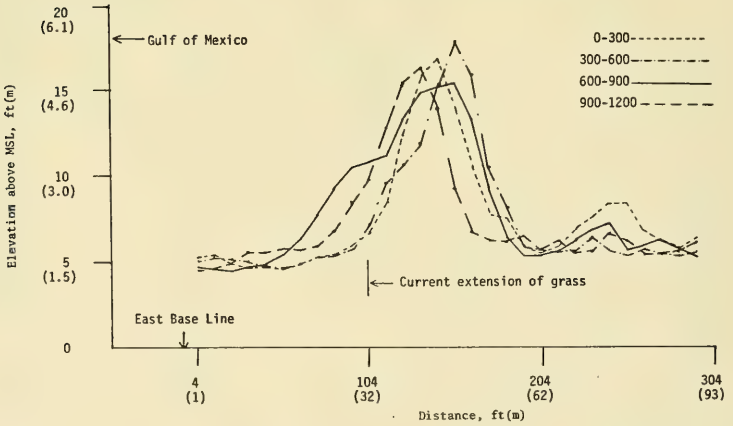


Figure 17. Mean cross-sectional profiles of the four designated dune segments of the 1,200-foot bitter panicum dune. Profiles extend 290 feet across the foredunes. Each is the mean of three profiles surveyed in August 1976.

Table 4. Sand volume for beach cross sections from 100 feet in front of dunes to 190 feet across the dunes.

Location	Volume by survey date, yd^3 (m^3)			
	Mar. 1975	Aug. 1975	Mar. 1976	Aug. 1976
	Total volume			
Unplanted area	67.3 (61.5)	68.6 (62.7)	69.2(63.3)	72.7 (66.5)
1,200-ft sea oats	82.9 (75.8)	86.8 (79.4)	87.8 (80.3)	89.1 (81.5)
Dune-width extension	82.8 (75.7)	85.8 (78.5)	87.0 (79.6)	90.0 (83.1)
1,100-ft bitter panicum	83.7 (76.5)	86.6 (79.2)	88.1 (80.6)	90.0 (82.3)
1,200-ft bitter panicum	73.6 (67.3)	75.8 (69.3)	76.6 (70.0)	81.4 (74.4)
	Volume above planting elevation[1]			
Unplanted area	24.4 (22.3)	25.7 (23.5)	26.3 (24.0)	29.7 (27.2)
1,200-ft sea oats	40.0 (36.6)	43.8 (40.1)	44.9 (41.1)	46.1 (42.2)
Dune-width extension	35.6 (32.6)	38.5 (35.2)	39.7 (36.3)	43.6 (39.9)
1,100-ft bitter panicum	36.4 (33.3)	39.4 (36.0)	40.9 (37.4)	42.7 (39.0)
1,200-ft bitter panicum	17.7 (16.2)	20.0 (18.3)	20.7 (18.9)	25.6 (23.4)

[1]Planting elevations: unplanted area, 4.0 feet; 1,200-foot sea oats, 4.0 feet; dune-width extension, 4.4 feet; 1,000-foot bitter panicum, 4.4 feet; 1,200-foot bitter panicum, 5.2 feet.

Table 5. Sand volume for 290-foot foredune cross sections above planting elevation.

Location	Planting dates	Planting elevation ft(m)	Volume, yd^3 (m^3) Mar. 1975	Aug. 1975	Mar. 1976	Aug. 1976
1. Unplanted natural area	Mar. 69	4.0 (1.2)	24.4 (18.6)	25.7 (19.6)	26.3 (20.1)	29.7 (22.7)
2. Planted areas						
a. 1,200-ft sea oats	Mar. 69	4.0 (1.2)				
North 400 ft (122 m)			35.3 (27.0)	38.6 (29.5)	39.6 (30.3)	42.9 (32.8)
Middle 400 ft (122 m)			39.6 (30.3)	43.3 (33.1)	44.8 (34.3)	45.9 (35.1)
South 400 ft (122 m)			47.1 (36.0)	51.0 (39.0)	52.6 (40.2)	51.6 (39.5)
Total 1,200 ft (366 m)			40.0 (30.6)	43.8 (33.5)	44.9 (34.3)	46.1 (35.2)
b. Dune-width extension	Oct. 69[1]	4.4 (1.3)	35.6 (27.2)	38.5 (29.4)	39.7 (30.4)	43.6 (33.3)
c. 1,100-ft bitter panicum	Feb. 70	4.4 (1.3)				
North 550 ft (168 m)			40.5 (31.0)	43.5 (33.3)	40.3 (30.8)	46.7 (35.7)
South 550 ft (168 m)			32.5 (24.8)	35.2 (26.9)	41.4 (31.7)	38.6 (29.5)
Total 1,100 ft (335 m)			36.4 (27.8)	39.4 (30.1)	40.9 (31.3)	42.7 (32.6)
d. 1,200-ft bitter panicum		5.2 (1.6)				
North 600 ft	Feb. 72					
0 to 300 ft (0 to 91 m)			17.7 (13.5)	18.8 (14.4)	20.4 (15.6)	25.5 (19.5)
300 to 600 ft (91 to 183 m)			16.6 (12.7)	20.0 (15.3)	19.0 (14.5)	23.6 (18.0)
Total north 600 ft (183 m)			17.2 (13.2)	19.4 (14.8)	19.7 (15.1)	24.6 (18.8)
South 600 ft	Apr. 72					
600 to 900 ft (183 to 274 m)			21.2 (16.2)	23.0 (17.6)	25.1 (19.2)	30.0 (22.9)
900 to 1,200 ft (274 to 366 m)			15.4 (11.8)	17.7 (13.5)	18.1 (13.8)	23.4 (17.9)
Total South 600 ft (183 m)			18.3 (14.0)	20.4 (15.6)	21.6 (16.5)	26.7 (20.4)
Total 1,200 ft (366 m)			17.7 (13.5)	20.0 (15.3)	20.7 (15.8)	25.6 (19.6)

[1]Dune-width extension plantings were on different months in 1969; October was used as an average date.

Table 6. Rate of sand accumulation in 290-foot foredune cross sections above planting elevation.

Location	Planting dates	Planting elevation, ft(m)	Accumulation per year, $yd^3(m^3)$ Planting to Mar. 75	Mar. 75 to Aug. 75	Aug. 75 to Mar. 76	Mar. 76 to Aug. 76	Aug. 75 to Aug. 76	Planting to Aug. 1976
1. Unplanted natural area	Mar. 69	4.0 (1.2)	4.1 (3.1)	3.1 (2.4)	1.0 (0.8)	8.1 (6.2)	4.0 (3.1)	4.0 (3.1)
2. Planted areas								
a. 1,200-ft sea oats								
North 400 ft (122 m)	Mar. 69		5.9 (4.5)	7.9 (6.0)	1.7 (1.3)	7.9 (6.0)	4.3 (3.3)	5.8 (4.4)
Middle 400 ft (122 m)	Mar. 69		6.6 (5.0)	8.8 (6.7)	2.6 (2.0)	2.6 (2.0)	2.6 (2.0)	6.2 (4.7)
South 400 ft (122 m)	Mar. 69		7.8 (6.0)	9.3 (7.1)	2.8 (2.1)	-2.4 (-1.8)	0.6 (0.5)	7.0 (5.4)
b. Dune-width extension	Oct. '69[1]	4.4 (1.3)	6.6 (5.0)	6.9 (5.3)	2.1 (1.6)	9.3 (7.1)	5.1 (3.9)	6.4 (4.9)
c. 1,100-ft bitter panicum		4.4 (1.3)						
North 550 ft (168 m)	Feb. 70		8.0 (6.1)	7.1 (5.4)	-5.5 (-4.2)	15.2 (11.6)	3.2 (2.4)	7.2 (5.5)
South 550 ft (168 m)	Feb. 70		6.4 (4.9)	6.4 (4.9)	10.7 (8.2)	-6.7 (-5.1)	3.4 (2.6)	5.9 (4.5)
Total 1,100 ft (335 m)			7.2 (5.5)	7.1 (5.4)	2.6 (2.0)	4.3 (3.3)	3.3 (2.5)	6.6 (5.0)
d. 1,200-ft bitter panicum		5.2 (1.6)						
North 600 ft								
0 to 300 ft (0 to 91 m)	Feb. 72		5.7 (4.4)	2.6 (2.0)	2.8 (2.1)	12.1 (9.3)	6.7 (5.1)	5.7 (4.4)
300 to 600 ft (91 to 183 m)	Feb. 72		5.4 (4.1)	8.1 (6.2)	-1.7 (-1.3)	11.0 (8.4)	3.6 (2.8)	5.2 (4.0)
Total north 600 ft			5.6 (4.3)	5.2 (4.0)	0.5 (0.4)	11.7 (8.9)	5.2 (4.0)	5.5 (4.2)
South 600 ft								
600 to 900 ft (183 to 274 m)	Apr. 72		7.3 (5.6)	4.3 (3.3)	3.6 (2.8)	11.7 (8.9)	7.0 (5.4)	6.9 (5.3)
900 to 1200 ft (274 to 366 m)	Apr. 72		5.3 (4.1)	5.5 (4.2)	0.7 (0.5)	12.6 (9.6)	5.7 (4.4)	5.4 (4.1)
Total south 600 ft (183 m)			6.3 (4.8)	5.0 (3.8)	2.1 (1.6)	12.1 (9.3)	6.3 (4.8)	6.2 (4.7)
Total 1,200 ft (366 m)			5.9 (4.5)	5.5 (4.2)	1.2 (0.9)	11.7 (8.9)	5.6 (4.3)	5.8 (4.4)

[1]Dune-width extension plantings were in different months in 1969; October was used as an average date.

exist. The major difference between this area and the planted dune areas is that the planted dunes present a solid wall of resistance to sand moving inland, so migrating sand from the beach accumulates on the dune face. On the unplanted area, the front "wall" is not solid so migrating sand penetrates through and over a broader base. The result is a relatively high "floor", around 7.6 feet (2.3 meters) MSL among the scattered pimple dunes. In contrast, the floor elevation behind and among the dunes of the planted study areas is only about 5.6 feet (1.7 meters) MSL. The missing 2 feet (0.6 meter) of sand from the floor of the planted areas has accumulated in the high elevation dunes formed as a result of sand trapped in the vegetated segments from the intentional plantings (Fig. 18).

Although constructed dunes should have a broader base than 80 to 90 feet (24 to 27 meters), which is the base width of the planted dunes, waiting for the broader base to occur naturally is not always useful. There are advantages to providing a uniform sand-trapping field immediately following denudation, such as occur during hurricanes of the severity of Hurricane Carla in 1961. These are:

(a) Highly mobile sand is rapidly confined to one area of accumulation, hence it is not lost to the beach system.

(b) The resultant wall of accumulating sand prevents storm surges of moderate intensity that occur annually from saltwater moving inland, and at the same time the accumulating sand acts as a dam for rainwater to provide a mesic environment free from saltwater on the bayward side of the plantings so that invading vegetation intolerant to salt can become rapidly established.

(c) After moderate accumulation of sand, little salt spray penetrates beyond the fore part of the planted dune, further hastening the establishment of island vegetation intolerant of salt spray.

d. Crest Elevations of Experimental Dunes. Longitudinal surveys which parallel the beach were made along the east and west crests of all planted dunes. No definable dune existed in the unplanted study area so no longitudinal surveys were made there. Figures 19 to 23 graphically show the east crest survey data. The longitudinal figures are more revealing than the cross-section figures for ascertaining effective height of dunes. It is also easier to show where relatively more sand is accumulating; e.g., the south 700 feet (213 meters) of the sea oats dune is 4 to 5 feet (1.2 to 2.5 meters) higher than the north 500 feet

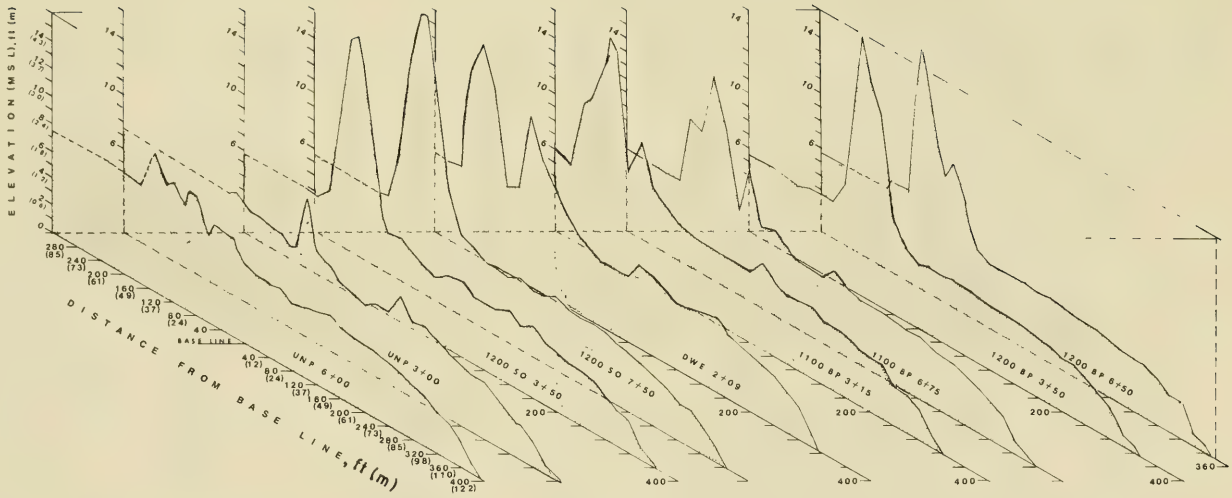


Figure 18. Cross-sectional profiles for August, 1976 for all stations that included a beach segment.

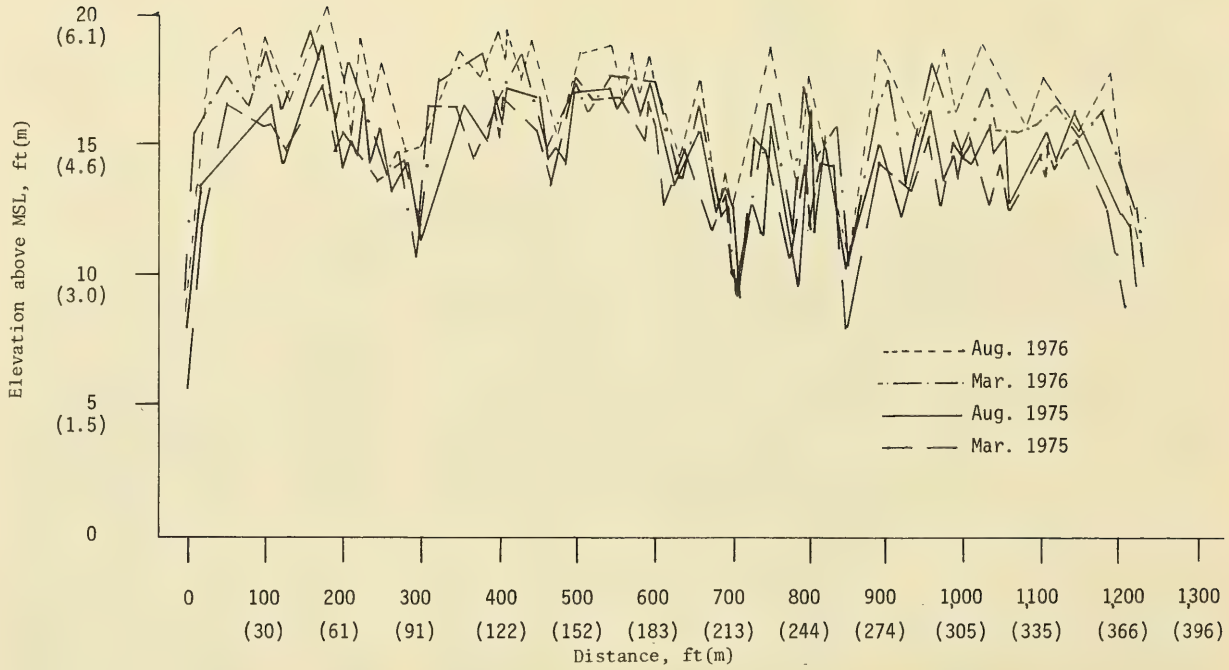


Figure 19. Longitudinal profiles along crest of the 1,200-foot bitter panicum dune, measured from the north end of the dune.

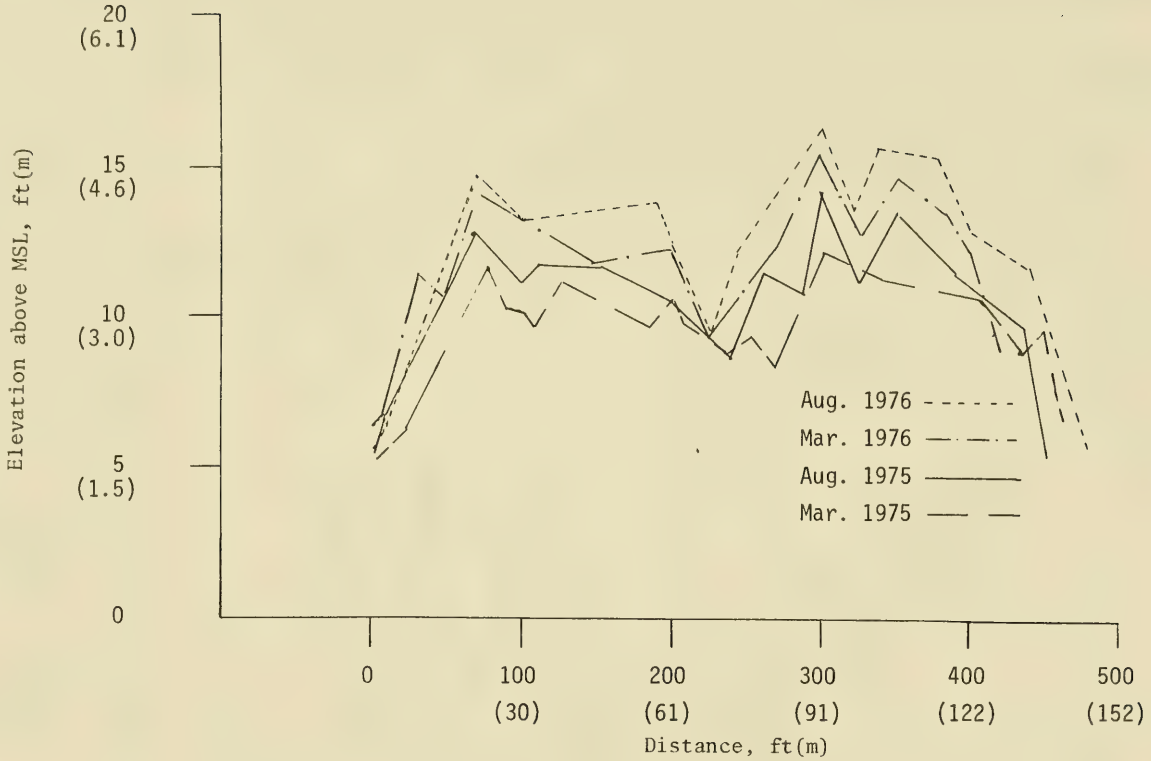


Figure 20. Longitudinal profiles along east crest of the dune-width extension dune, measured from the north end of the dune.

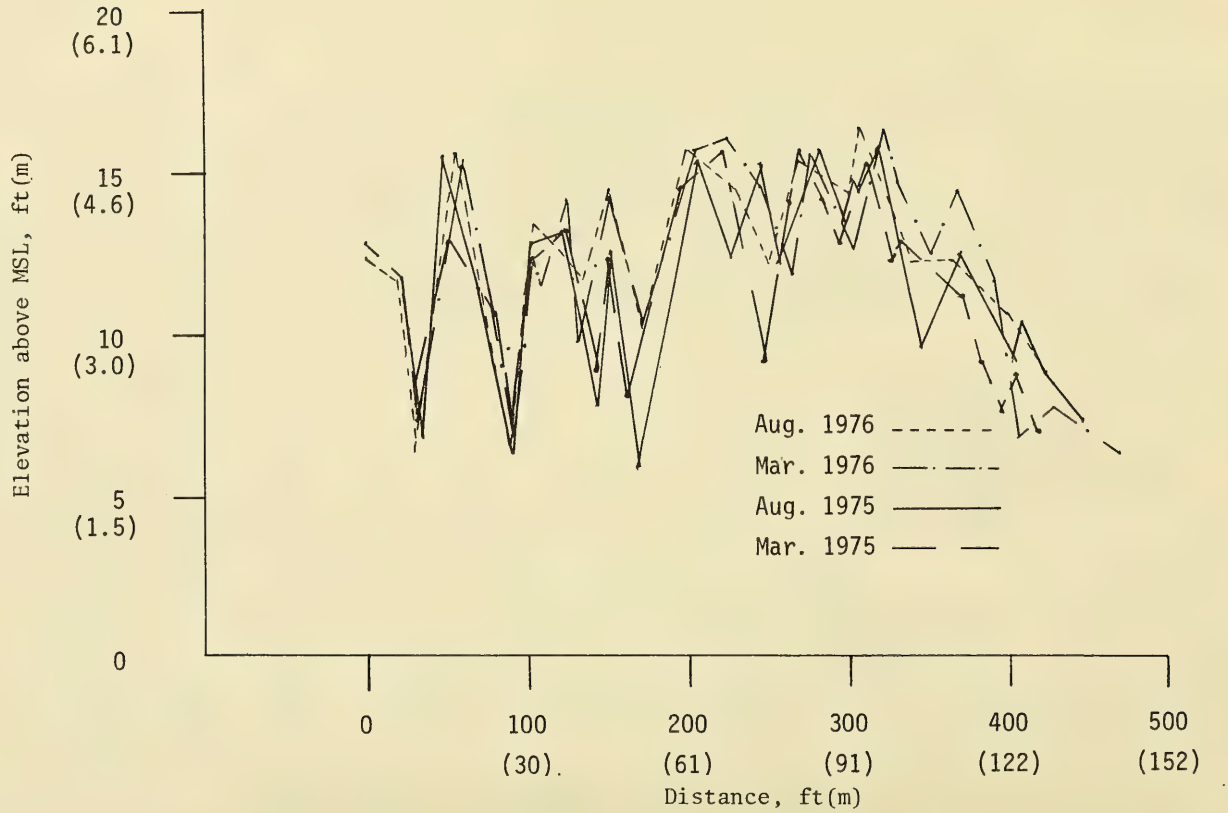


Figure 21. Longitudinal profiles along west crest of the dune-width extension dune, measured from the north end of the dune.

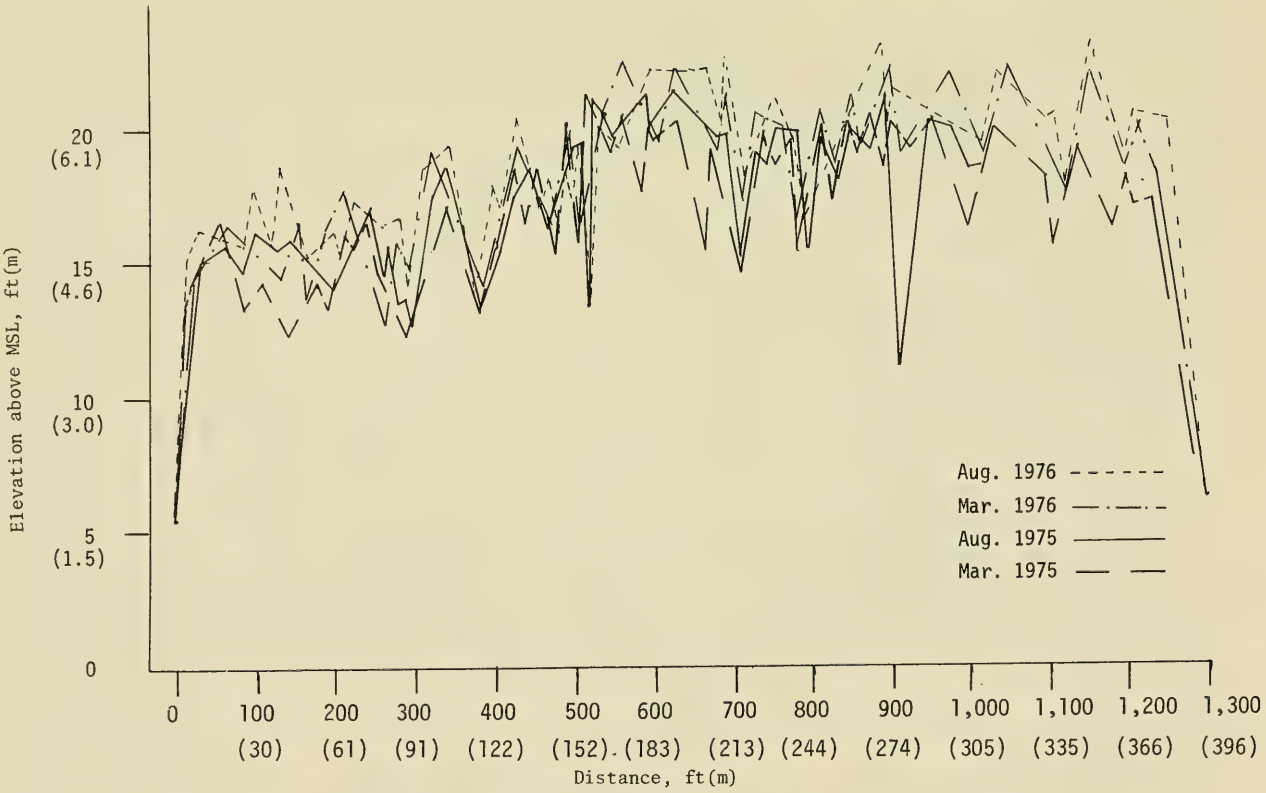


Figure 22. Longitudinal profiles along crest of the 1,200-foot sea oats dune, measured from the north end of the dune.

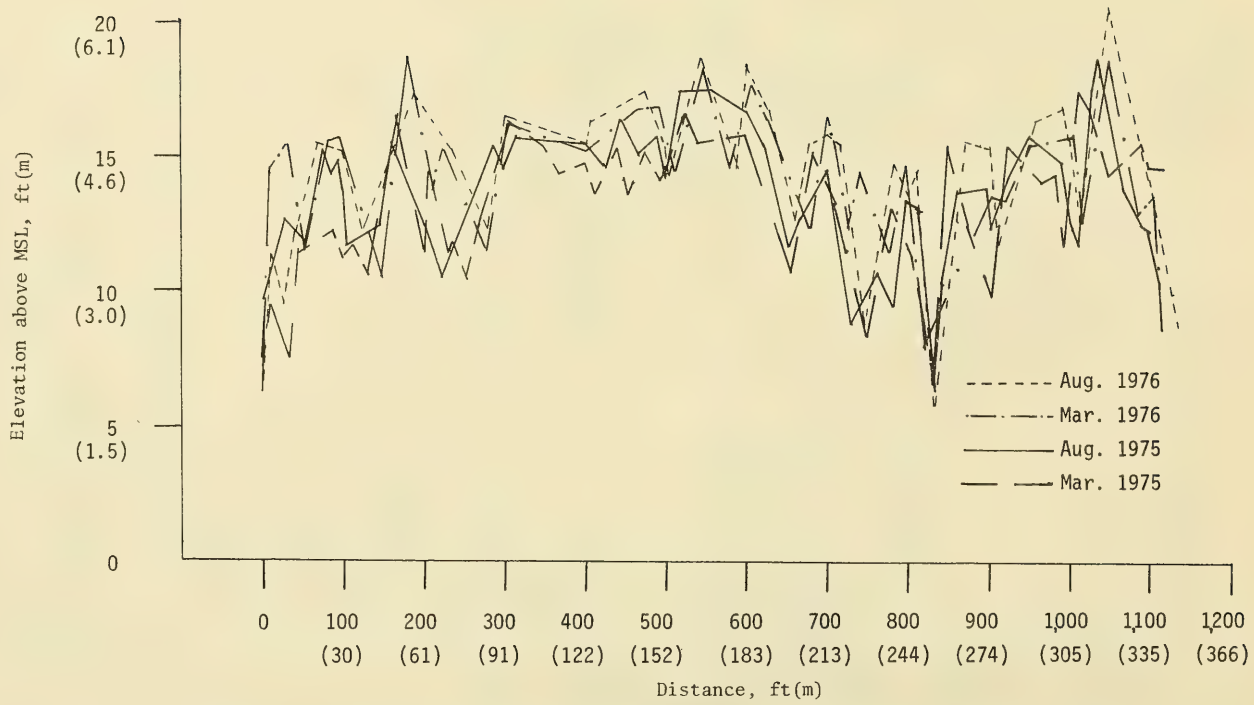


Figure 23. Longitudinal profiles along crest of the 1,100-foot bitter panicum dune, measured from the north end of the dune.

(152 meters) (Fig. 22). The sand volume values (Table 5) show this; the longitudinal figure is just graphic verification. The poorer initial stands of the south 600 feet of both the 1,100- and 1,200-foot bitter panicum dunes are readily apparent from the less uniform profiles and the deep cuts through the dunes (Figs. 19 and 23). Such profiles also provide an instant evaluation of the effectiveness of the overall dune-building research. Although some of the deep canyons through the dunes begin to heal in time, the canyons are mostly quite persistent and will probably require mechanical repair to completely heal them; e.g., most deep cuts present in March 1975 were still very much in evidence in August 1976. How to repair these obvious "leaks" is an area that should be further researched. Perhaps, stacking bales of hay in the cuts and tying the bales to the canyon walls with netting to reduce the wind velocity would allow healing. Such treatment would probably be relatively inexpensive yet effective.

2. Vegetative Transects.

Vegetation on Experimental Dunes. Sea oats and bitter panicum have laterally spread slowly on Padre Island. From a 50-foot planting width in March 1969, the sea oats has spread seaward 5.25 feet (1.6 meters) per year (Table 7).

While the bitter panicum has spread slightly faster since planting than the sea oats, it is doubtful that one will actually spread any faster than the other. Note that for August 1975 to August 1976, the sea oats spread more than the bitter panicum (Table 7).

If it is assumed that a 125-foot base is needed for a restored foredune, it is apparent that attaining such a base from a single 50-foot-wide planting will take about 15 years with either species. If a wide base is desired in as short a period as possible, the technique of following an initial 50-foot planting with a second 50-foot planting on the beach side in 4 years appears to be the better method. The best method will be known once these study dunes are subjected to direct hurricane attack.

(1) Extension of Planted Species. In reviewing the species reported for transects measured in 1971 and 1973 (Dahl, et al., 1975), the species commonly found in 1975 and 1976 transects were the same and little change in relative composition occurred except a tendency for increased proportion of grasses. Basic differences in the 1975 and 1976 surveys were largely in percent cover and frequency of occurrence. Apparently, growing conditions were better in 1976 than in 1975 as ground cover was often 100 percent greater (Table 8). Generally, sea oats tended to increase, occurring more frequently on almost all transects. Bitter panicum tended to remain more stable with only

Table 7. Rate of lateral spread of planted grasses.

Area	Planting date	Extent of grass, ft (m)				Annual Rate of Extension
		Mar. 1975	Aug. 1975	Mar. 1976	Aug. 1976	
1,200-ft sea oats	Mar. 1969	75(23)	82(25)	86(26)	89(27)	5.25(1.6)
Dune-width extension	Oct. 1969	130(40)	137(42)	130(40)	137(42)	5.41(1.7)
1,100-ft bitter panicum	Feb. 1970	77(23)	84(26)	87(27)	89(27)	6.00(1.8)
1,200-ft bitter panicum	Mar. 1972	72(22)	78(24)	76(23)	82(25)	7.24(2.2)

Table 8. Total percent cover for all vegetation from transects measured at various locations in the five study areas.

Study area	Seaward slope		Landward slope		25 ft landward of dune		125 ft landward of dune		225 ft landward of dune	
	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
Unplanted natural area	9	27	22	30	27	25	20	31	21	27
1,200-ft sea oats dune	12	31	12	39	27	40	31	35	42	40
Dune-width extension	21	52	17	40	15	18	28	71	30	57
1,100-ft bitter panicum	23	36	19	45	17	42	22	33	31	42
1,200-ft bitter panicum	28	61	28	41	17	24	12	18	25	44

slight increases noted. Seashore dropseed tended to decline or remain the same. There were no significant increases.

(2) Invasion of Unplanted Species. Invasion of unplanted species into experimental dunes has been slower than anticipated. For example, the 1,200-foot sea oats dune has been under test since March 1969, yet only four species other than those planted occurred commonly enough to be considered a significant invader (Table 9). Gulf croton and the *Ipomoea* spp. occur sporadically. This lack of unseeded species in dunes from experimental plantings after 7 or 8 years is best explained by comparing species composition on mature dunes of the area formed naturally to the unplanted study area and the dunes from experimental plantings of this study. Gulf croton, beach evening primrose, *Physalis* species, beach morning glory, and other grasses are relatively common in mature, naturally formed dunes. These species are also much more common on the unplanted, naturally formed dunes in this study. Apparently, if a dune forms naturally with the pioneering plants available to the area, some species remain from previous successional stages and they are a natural component of the mature dune at successional climax. However, some of the pioneer successional stages have been bypassed through planting a grass monoculture. Hence, some normal dune species were unable to find a niche and become established. It becomes apparent that a multispecies dune will develop very slowly if originated from grass plantings.

V. DISCUSSION

1. Evaluation of Dune-Widening Methods.

During experimental plantings from 1969 to 1974, the 1,200-foot bitter panicum and the dune-width extension plantings were specifically made to find the most effective way to widen the base of dunes constructed from vegetation plantings. In February 1972, 600 feet of beach was planted with bitter panicum. The north 300 feet was 50 feet wide with individual transplants spaced 2 feet apart in rows 2 feet apart. The plantings from 300 to 600 feet were the same except planting width was 100 feet. In April 1972, another 600 feet was added to the south end of the February planting. The plantings width was 50 feet for the 600 to 900 feet, and 100 feet for the 900 to 1,200 feet. However, individual transplants were placed 2 feet apart in 4-foot rows rather than in 2-foot rows.

Data accumulated during the past 2 years for the 1,200-foot bitter panicum dune are in Tables 5 and 6 and Figures 10, 16, and 17. Briefly, the results of this study are:

(a) A 50-foot-wide planting trapped all available sand from the beach, so it was unnecessary to plant a

Table 9. Sum of Importance Values (IV)[1] for common species (planted and invading) for experimental dunes.

Species	Unplanted natural area		1,200-ft sea oats		Dune-width extension		1,100-ft bitter panicum		1,200-ft bitter panicum	
	1975	1976	1975	1976	1975	1976	1975	1976	1975	1976
Panicum amarum	0	0	97	9	2,819	7,063	2,688	4,874	5,432	9,823
Sporobolus virginicus	0	0	0	0	0	0	0	0	0	0
Uniola paniculata	102	178	1,382	4,070	296	699	72	179	3	27
Fimbristylis spp.	6	0	0	0	9	0	0	0	0	0
Croton punctatus	178	628	1	9	0	0	0	8	0	0
Oenothera drummondii	23	148	3	88	1	2	16	110	1	0
Hydrocotyle bonariensis	0	0	0	0	0	0	0	0	0	0
Samolus ebracteatus	0	0	0	0	0	0	0	0	0	0
Ipomoea stolonifera	1,558	2,509	1	0	0	0	2	37	0	0
Bacopa monnieri	0	1	0	0	0	0	0	0	0	0
Erigeron myrionactis	0	1	0	2	0	0	0	0	0	0

[1]Importance Value = product of percent frequency X percent cover.

100-foot-wide strip.

(b) A 2-foot plant spacing with high transplant survival (76 percent) gave a very uniform, tall, but narrow-based dune.

(c) Rows 4 feet apart with intermediate transplant survival (36 or 18 percent if based on 2-foot rows) gave a less uniform, lower elevation, but broader based dune than the dune part constructed from 2-foot transplant spacing.

The longitudinal survey (Fig. 19) indicates that the effective height of dune is considerably less for the south 600 feet of the dune constructed with the 4-foot row spacings. Yet, the base of this part of the dune varies from 65 to 100 feet (20 to 30 meters) compared to a more uniform 75-foot (23 meters) width for the north 600 feet. Effectiveness of the more variable, but broader based, more "ragged topped" dune may be as good as the narrower more uniform, taller north segment. If transplant survival of 40 percent or greater is expected, there is no reason to double the plant material required by using 2-foot row spacing. However, the 40 percent survival is uncertain, so a safer way would be to stay with the 2-foot spacings.

A more effective way to extend dune width than making an initially wide planting is to allow a more narrow planting to grow to some predetermined height, e.g., 12 feet (3.7 meters), then make a second planting in front (seaward). The dune-width extension area was initially planted with bitter panicum in 1969. In April 1973, a 50-by 400-foot strip of bitter panicum was planted immediately gulfward of the earlier established dune. Figure 14 shows that this dune has a base at least 125 feet wide and a mean elevation of about 14 feet (4.3 meters). Figures 20 and 21 show that the effective height is probably only 10 feet but the wider base should allow this dune to be more effective in withstanding severe surges with prolonged wave attack than the taller more narrow-based dunes.

2. Rate of Sand Accumulation and/or Loss.

Since beach sand volumes were not specifically measured during the first phase of this study (Dahl, et al., 1975), several years of data on which to determine rate of accretion or erosion was unavailable. However, the net sand accumulation from August 1975 to August 1976 should provide an indication. For the study locations monitored, the average new sand per linear foot of beach, at a 655-foot distance inland, was 5.7 cubic yards. This was 1.4, 0.2, 11.0, 8.9, and 7.0 cubic yards (1.1, 0.2, 8.4, 6.8, and 5.4 cubic meters) for the unplanted, 1,200-foot sea oats, dune-width extension, 1,100-foot bitter panicum, and 1,200-foot bitter

panicum area, respectively (Table 2).

a. Foredune Accumulation. Despite the fact that the two northern locations are apparently receiving little new sand now, they apparently have previously because in the area of the plantings they continue to accumulate sand at a significant rate (Table 6). As indicated previously, the unplanted foredune area from August 1975 to August 1976 accumulated 4.0 cubic yards per linear foot of beach versus 2.3 and 3.3 cubic yards (3.1 cubic meters per linear meter of beach versus 1.8 and 2.5 cubic meters) for the 1,200-foot sea oats and 1,100-foot bitter panicum dunes, respectively (Table 6). However, if yearly trapping rates from the time of planting through the August 1976 measurements are considered, the planted segments are still well ahead with 6.25 versus 4.0 cubic yards per linear foot (4.8 versus 3.1 cubic meters per linear meter) of beach per 290-foot cross section.

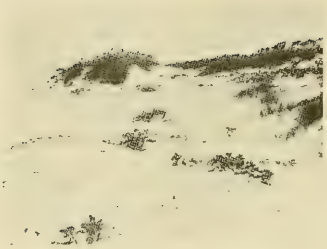
Enough vegetation, primarily sea oats, has become established in front of the plantings that significant volumes of sand are trapped in front of the planted dunes (Fig. 24). This is believed to be responsible for the low amount of sand accumulating in the middle and south segments of the 1,200-foot sea oats dune (Table 5).

If periodic studies are made on these plantings, a special effort should be made to find the rate of natural dune replacement and how rapidly the vegetation in the foredune area reaches the same status as that behind planted dunes. Presently, the unplanted dune area appears more arid than that behind the planted dunes (Fig. 25).

b. Beach Erosion or Accretion. Apparently, a major source of concern relative to beach processes is, what will a particular action do to erosional and depositional patterns? Table 10 gives the distances from the east base line (App. A) to MSL. Although variations of 30 feet were common from date to date, surprisingly little change was recorded overall for the four measurements. There was probably no actual change during this period other than normal short-term fluctuations.

c. Net Losses or Gains. Brown, et al. (1976) reported that northern Padre Island is in a period of relative stability. However, they believe that during the past 125 years the island has entered an erosional phase, and that the volume of sediment being supplied to the Corpus Christi area has reached a critical deficiency. Therefore, the long-term trend is erosional rather than accreting.

The data in this study tend to indicate slight erosion on the north end (Table 7) and a stable beach from the dune-width extension south. This trend also agrees with the relative sand volume data reported by Brown, et al. (1976).



a. Dune-width extension

b. 1,200-ft bitter panicum

Figure 24. Sand accumulation gulf side of foredunes.

a. Unplanted natural area

b. 1,200-ft sea oats

c. 1,200-ft bitter panicum

Figure 25. Vegetation establishment bayward of foredunes.

Table 10. Distances from the east base line to MSL for the study locations with beach cross-sectional profiles.

Beach profile	Distance by survey date, ft(m)			
	Mar. 1975	Aug. 1975	Mar. 1975	Aug. 1975
Unplanted natural area				
6+00 station	361 (110)	399 (122)	413 (126)	395 (120)
3+00 station	418 (127)	433 (132)	392 (119)	407 (124)
"A1" bench mark		402 (123)	376 (115)	380 (116)
1,200-ft sea oats				
3+50 station	363 (111)	400 (122)	360 (110)	367 (112)
7+50 station	338 (103)	390 (119)	351 (107)	346 (105)
Dune-width extension				
2+09 station		305 (93)	336 (102)	302 (92)
1,100-ft bitter panicum				
3+15 station	331 (101)	319 (97)	293 (89)	339 (103)
6+75 station	329 (100)	329 (100)	389 (119)	354 (108)
"Kenny" bench mark		341 (104)	336 (102)	337 (103)
1,200-ft bitter panicum				
3+50 station	290 (88)	343 (105)	347 (106)	331 (101)
6+50 station	341 (104)	327 (100)	349 (106)	353 (108)
Avg. (all stations)	346 (105)	363 (111)	358 (109)	353 (108)

3. Vegetative Differences Between Planted Dunes and Naturally Forming Dunes.

When the area behind naturally forming foredunes is compared to the planted foredunes, there is an obvious appearance of a more arid environment in the unplanted natural dune area (Fig. 25). The more mesic microclimate bayward of experimental plantings is believed to be due to the damming effect provided by the resultant dunes. These dunes retain rainwater in the middune area, providing a more favorable habitat and becoming more free of salt spray than the area behind the unplanted naturally forming dune. The obvious differences as reflected by the vegetation measurements are as follows:

(a) The perennial grasses (bitter panicum, seashore dropseed, and sea oats) are found only occasionally in and behind the unplanted dune area, but are common behind the other dunes. The sea oats is increasing rapidly in all but the unplanted area (Table 11).

(b) Gulf croton is quite common on the unplanted study area, but nearly absent behind the planted study areas. Gulf croton is believed to be a very drought tolerant species and in this case one indicative of a more arid microenvironment.

(c) Beach evening primrose and beach morning glory were apparently at home in both environments.

(d) The *Fimbristylis* species, *Hydrocotyle bonariensis*, and *Bacopa monnieri* all apparently require a more mesic habitat; they were only found in low areas behind the dunes. Their near absence (Table 11) from the unplanted study area is also believed indicative of relative aridity among the experimental sites.

Table 11. Sum of Importance Values (IV)[1] for common species becoming established within 225 feet of the planted dunes (bayward).

Species	Unplanted natural area		1,200-ft sea oats		Dune-width extension		1,100-ft bitter panicum		1,200-ft bitter panicum	
	1975	1976	1976	1976	1975	1976	1975	1976	1975	1976
Panicum amarum	0	0	128	10	156	21	183	1,002	303	253
Sporobolus virginicus	1	2	687	744	135	46	23	17	2	9
Uniola paniculata	2	1	62	171	130	280	330	843	415	611
Fimbristylis spp.	78	4	1,485	364	1,259	1,514	269	1,498	505	414
Croton punctatus	850	499	10	3	5	5	19	1	30	20
Oenothera drummondii	652	464	272	393	779	631	609	995	558	709
Hydrocotyle bonariensis	1	7	1,023	445	26	39	9	46	0	1
Samolus ebracteatus	1	3	112	183	15	430	3	76	1	87
Ipomoea stolonifera	1,826	2,157	7	11	524	1,166	172	125	72	147
Bacopa monnieri	2	73	500	33	77	4	12	3	5	32
Erigeron myrionactis	1	81	17	16	54	22	9	229	10	76

[1]Importance Value = product of percent frequency X percent cover.

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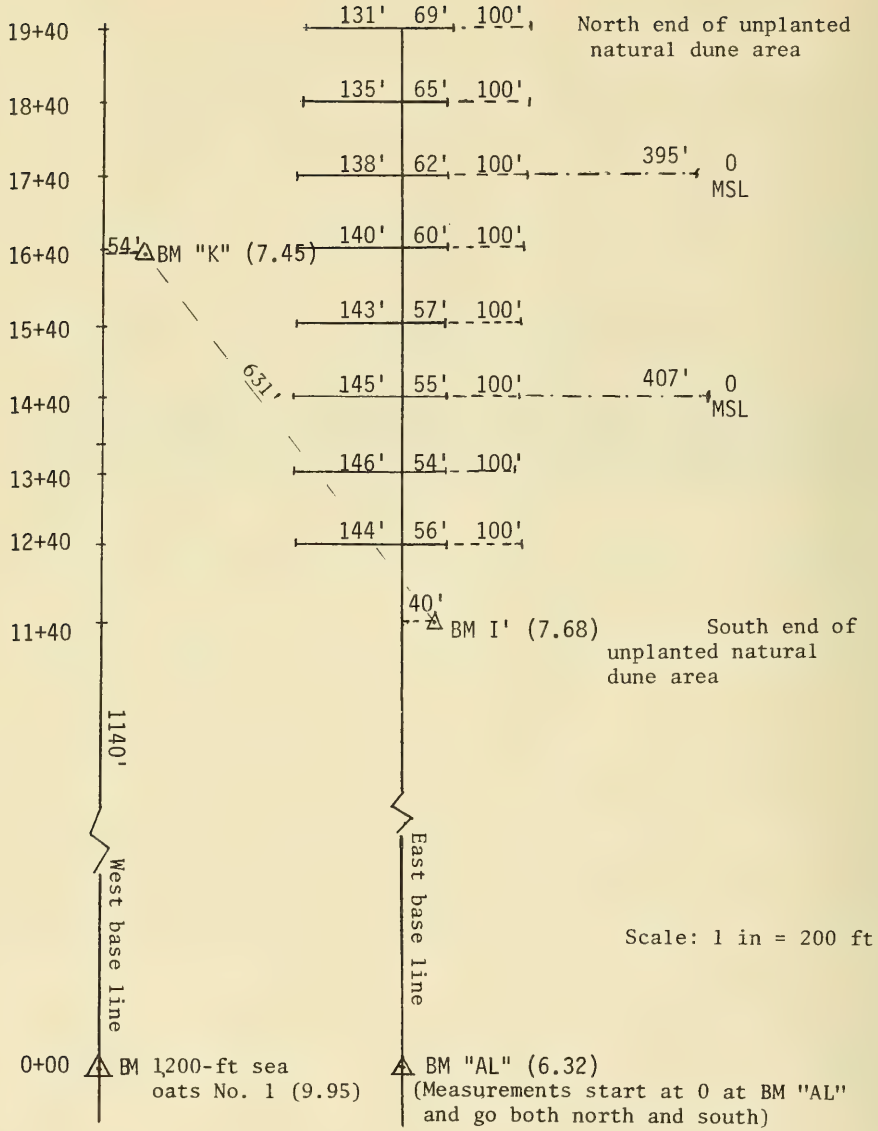
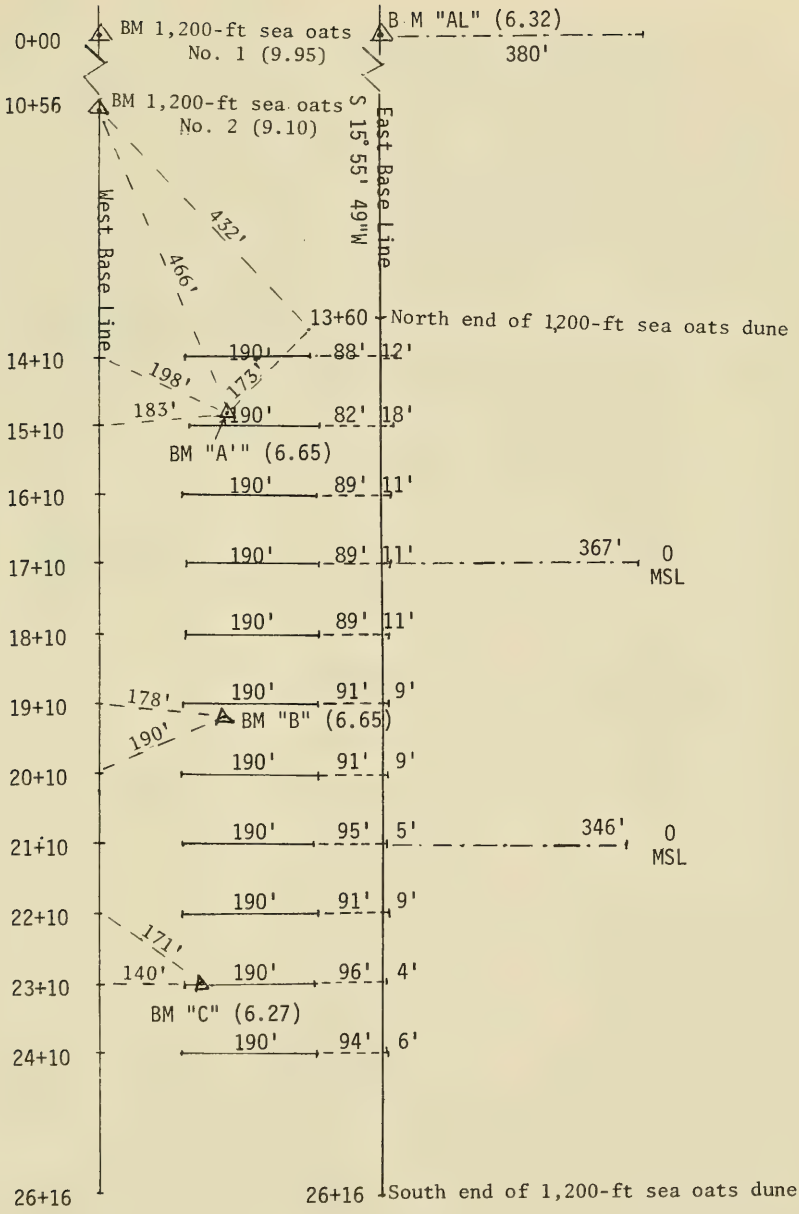
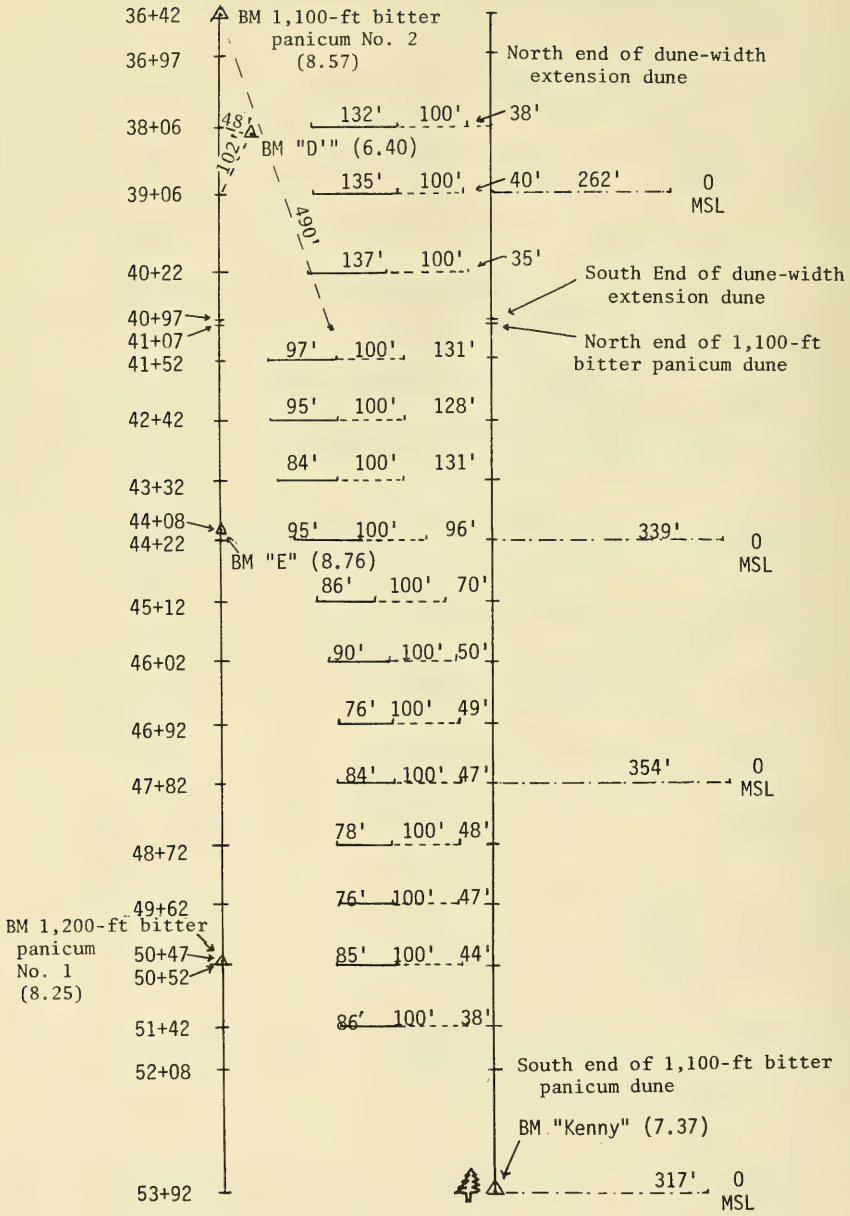
APPENDIX A

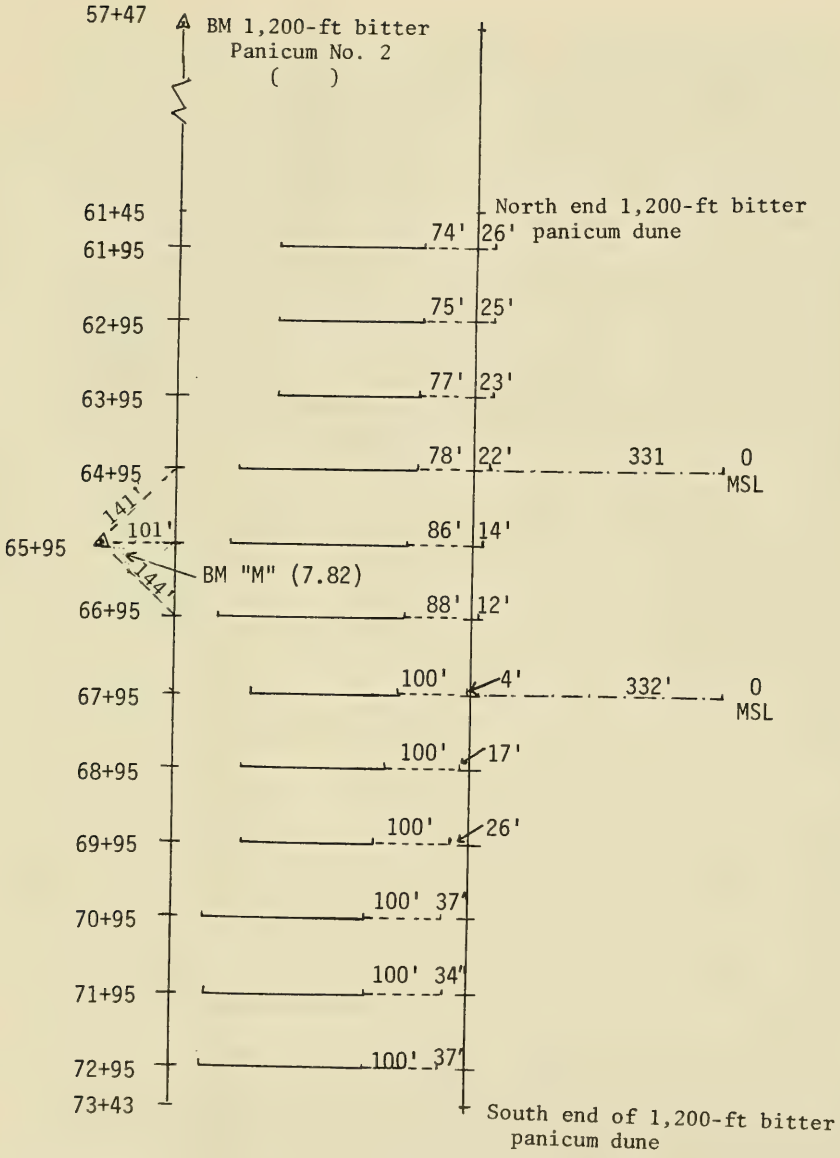
DETAILED DIAGRAM OF NORTH PADRE ISLAND STUDY PLOTS

Beach measurements shown are the distances to the base line; foredune measurements include the 100 feet gulfward from front of dune (grass extension) and the length of measured cross section except for dune-width extension and 1,100-foot bitter panicum dunes where distance indicated is to the back of the dune only.


19+40
18+40
17+40
16+40
15+40
14+40
13+40
12+40
11+40
0+00
131' 69' 100'
North end of unplanted natural dune area
135' 65' 100'
138' 62' 100'
395'
0 MSL
140' 60' 100'
54'
BM "K" (7.45)
143' 57' 100'
631'
145' 55' 100'
407'
0 MSL
146' 54' 100'
144' 56' 100'
40'
BM I' (7.68)
South end of unplanted natural dune area
1140'
West base line
East base line
Scale: 1 in = 200 ft
BM 1,200-ft sea oats No. 1 (9.95)
BM "AL" (6.32)
(Measurements start at 0 at BM "AL" and go both north and south)


0+00
BM 1,200-ft sea oats No. 1 (9.95)
B M "AL" (6.32)
380'
10+56
BM 1,200-ft sea oats No. 2 (9.10)
S 15° 55' 49"W
West Base Line
East Base Line
432'
466'
13+60
North end of 1,200-ft sea oats dune
14+10
190'
88'
12'
198'
173'
183'
15+10
190'
82'
18'
BM "A'" (6.65)
16+10
190'
89'
11'
17+10
190'
89'
11'
367'
0 MSL
18+10
190'
89'
11'
19+10
178'
190'
91'
9'
BM "B" (6.65)
20+10
190'
91'
9'
21+10
190'
95'
5'
346'
0 MSL
22+10
190'
91'
9'
171'
23+10
140'
190'
96'
4'
BM "C" (6.27)
24+10
190'
94'
6'
26+16
26+16
South end of 1,200-ft sea oats dune


36+42
BM 1,100-ft bitter panicum No. 2 (8.57)
36+97
North end of dune-width extension dune
38+06
48'
102'
132'
100'
38'
BM "D'" (6.40)
39+06
135'
100'
40'
262'
0 MSL
490'
40+22
137'
100'
35'
South End of dune-width extension dune
40+97
41+07
North end of 1,100-ft bitter panicum dune
41+52
97'
100'
131'
42+42
95'
100'
128'
43+32
84'
100'
131'
44+08
44+22
95'
100'
96'
339'
0 MSL
BM "E" (8.76)
45+12
86'
100'
70'
46+02
90'
100'
50'
46+92
76'
100'
49'
47+82
84'
100'
47'
354'
0 MSL
48+72
78'
100'
48'
49+62
76'
100'
47'
BM 1,200-ft bitter panicum No. 1 (8.25)
50+47
50+52
85'
100'
44'
51+42
86'
100'
38'
52+08
South end of 1,100-ft bitter panicum dune
BM "Kenny" (7.37)
53+92
317'
0 MSL


57+47
BM 1,200-ft bitter
Panicum No. 2
( )
61+45
North end 1,200-ft bitter
61+95
74' 26' panicum dune
62+95
75' 25'
63+95
77' 23'
64+95
78' 22'
331
0
MSL
141'
65+95
101'
86' 14'
BM "M" (7.82)
144'
66+95
88' 12'
67+95
100'
4'
332'
0
MSL
68+95
100'
17'
69+95
100'
26'
70+95
100' 37'
71+95
100' 34'
72+95
100' 37'
73+43
South end of 1,200-ft bitter
panicum dune

APPENDIX B

COMPOSITION OF VEGETATION ALONG FIVE TRANSECTS
IN FOREDUNE SECTION OF STUDY DUNES

Table B-1. Percent frequency and cover for the unplanted natural area.

	FOREDUNE								BAY SIDE OF DUNE											
	Foreslope				Backslope				25 ft west				125 ft west				225 ft west			
	1975		1976		1975		1976		1975		1976		1975		1976		1975		1976	
Gramineae	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover
Cynodon dactylon											2	T	3	T	2	T				
Panicum amarum																				
Panicum amarulum											3	1								
Paspalum monostachyum							3	T			7	1								
Spartina patens			3	T			13	1												
Sporobolus virginicus			10	T	2	T	5	T	10	T	12	T			5	T				
Uniola paniculata	22	1	37	4	28	3	20	1	5	T	7	T								
Cyperaceae																				
Cyperus esculentus																			8	T
Eleocharis alida											3	T							8	T
Eleocharis caribaea																			20	1
Eleocharis parvula															3	T			8	T
Eleocharis spp.																				
Fimbristylis caroliniana	8	T			2	T			40	1			15	1	2	T	23	T	5	T
Fimbristylis castanea	12	T			5	T			13	2	5	T	23	T	2	T	8	T		
Aztoaceae																				
Sesuvium portulacastrum	2	T							5	T					2	T				
Lequminosae																				
Baptisia leucophaea																				
Cassia fasciculata					2		10	4			17	3	5		27	8			20	3
Euphorbiaceae																				
Croton capitatus																				
Croton punctatus	32	3	42	7	28	3	50	7	35	4	30	1	43	7	48	6	58	7	43	5
Euphorbia ammanioides			10	T			3	T	10	T	3	T			3	T			3	T
Onagraceae																				
Oenothera drummondii		T	20	2	12	2	37	3	40	5	42	3	40	4	67	4	48	6	45	2
Oenothera spp.																				
Umbelliferae																				
Hydrocotyle bonariensis											3	T	8	T	2	T			10	1
Primulaceae																				
Samolus ebracteatus									8	T	3	T			3	T			3	T
Gentianaceae																				
Eustoma exaltatum											3	T			20	1			20	1
Sabatia arenicola			5	T			12	1			38	1	3	T	30	1			28	1
Convolvulaceae																				
Ipomoea pes-caprae	10	T	5	T	8	1	2	T	5	1	2	T	13	2	3	T	5	1	25	2
Ipomoea stolonifera	82	5	100	13	88	13	98	12	98	12	95	9	53	6	95	8	55	7	73	7
Solanaceae																				
Physalis viscosa							2	T							2	T				
Scrophulariaceae																				
Bacopa monnieri			5	T			3	T	3	T	17	3	3	T	7	T			13	2
Compositae																				
Erigeron myrionactis							3	T			30	2	3	T	13	T			28	1
Senecio riddellii																				
Verbenaceae																				
Phyla incisa											3								8	1

Table B-2. Percent frequency and cover for the 1,200-foot sea oats dune area.

	FOREDUNE								BAY SIDE OF DUNE											
	Foreslope				Backslope				25 ft west				125 ft west				225 ft west			
	1975		1976		1975		1976		1975		1976		1975		1976		1975		1976	
	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover
Gramineae																				
Cynodon dactylon									35	2	5	T	18	T	3	T	50	1	13	1
Panicum amarum			8	1	32	3	35	12	50	5	58	5	13	T	30	2	15	1	20	1
Panicum amarulum													30	3	8	3			13	3
Paspalum monostachyum									3	T			25	2	40	5	8	T	35	5
Spartina patens							3	T							5	T			3	T
Sporobolus virginicus									43	2	63	6	75	3	63	5	75	5	40	2
Uniola paniculata	97	12	97	27	65	4	75	20			23	5	25	2	20	3	3	T	8	1
Cyperaceae																				
Cyperus esculentus																				
Eleocharis alida											35	2			15	T			13	1
Eleocharis caribaea															28	3			38	2
Eleocharis parvula											30	2							3	1
Eleocharis spp.									35	T			18	1			15	T		
Fimbristylis caroliniana									8	T			35	1	3	T	33	2		
Fimbristylis castanea									78	5	40	4	68	4	45	3	88	8	35	2
Aizoaceae																				
Sesuvium portulacastrum	10	T							10	T			8	T			8	T		
Leguminosae																				
Baptisia leucophaea																			3	T
Cassia fasciculata													5	1	5	1	8	3	35	3
Euphorbiaceae																				
Croton capitatus																	3	T		
Croton punctatus			5	2	2	1	5	T			3	T	10	1	5	T	8	T		
Euphorbia ammanioides			2	T	22	4	7	1	8	1	3	T	3	T	5	T	3	T	3	T
Onagraceae																				
Oenothera drummondii					8	T	18	5	8	T	13	3	45	6	55	3	28	1	38	5
Oenothera spp.																				
Umbelliferae																				
Hydrocotyle bonariensis									55	5	85	4	73	4	45	1	75	6	58	1
Primulaceae																				
Samolus ebracteatus									75	1	20	1	18	T	33	1	13	T	43	4
Gentianaceae																				
Eustoma exaltatum									25	T			20	T			55	1	5	T
Sabatia arenicola					2	T			10	T	25	T	28	T	18	T	48	1	40	1
Convolvulaceae																				
Ipomoea pes-caprae			8	1	2	T	2	T	15	1	3	T	8	T	3	T				
Ipomoea stolonifera	3	T											13	T	13	T	8	1	8	T
Solanaceae																				
Physalis viscosa							3	T	3	T	8	1			5	T	20	1	3	T
Scrophulariaceae																				
Bacopa monnieri									70	3	25	1	28	1	5	T	53	5	5	T
Compositae																				
Erigeron myrionactis							3	1			3	T	18	1	5	T			20	1
Senecio riddellii																				
Verbenaceae																				
Phyla incisa											8	2							10	1

Table B-3. Percent frequency and cover for the dune-width extension dune area.

	FOREDUNE								BAY SIDE OF DUNE											
	Foreslope				Backslope				25 ft west				125 ft. west				225 ft west			
	1975		1976		1975		1976		1975		1976		1975		1976		1975		1976	
Gramineae	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover
Cynodon dactylon																	20	T	5	T
Panicum amarum	100	21	98	51	72	10	78	26	30	5	15	1	5	1					3	T
Panicum amarulum															8	1				
Paspalum monostachyum																				
Spartina patens					2	T	3	T												
Sporobolus virginicus									5	T	5	T	25	T	38	1	65	2		
Uniola paniculata			3	T	53	6	53	13	15	2	18	3	23	5	28	8	20	T		
Cyperaceae																				
Cyperus esculentus									3	T	3	T								
Eleocharis alida															10	1				
Eleocharis caribaea											40	T							33	1
Eleocharis parvula															5	T			18	1
Eleocharis spp.																				
Fimbristylis caroliniana									5	T	3	T	30	1			15	T		
Fimbristylis castanea									75	2	80	4	85	4	70	9	88	8	80	7
Azioaceae																				
Sesuvium portulacastrum									12	T	3	T	8	T			5	T		
Leguminosae																				
Baptisia leucophaea																				
Cassia fasciculata					8	1	2	T	3	T	5	1	15	1	25	6			10	T
Euphorbiaceae																				
Croton capitatus													3	T						
Croton punctatus									5	T	3	T	10	T	5	1				
Euphorbia ammanioides					2	T									3	T			3	T
Onagraceae																				
Oenothera drummondii			2	T	2	1	2	1	20	3	23	2	80	7	65	9	43	5	23	1
Oenothera spp.																				
Umbelliferae																				
Hydrocotyle bonariensis									15	2	20	1					8	T	33	1
Primulaceae																				
Samolus ebracteatus											3	T	10	T	38	9	28	1	48	2
Gentianaceae																				
Eustoma exaltatum													26	T	3	T	28	1	3	T
Sabatia arenicola									5	T	30	1	65	1	30	2	43	1	5	T
Convolvulaceae																				
Ipomoea pes-caprae			2	T											5	T				
Ipomoea stolonifera									23	1	68	5	75	6	75	11	28	T	23	T
Solanaceae																				
Physalis viscosa																				
Scrophulariaceae																				
Bacopa monnieri									3	T	13	T	28	1	5	T	55	1		
Compositae																				
Erigeron myrionactis													10	T	15	1	43	1	10	T
Senecio riddellii																				
Verbenaceae																				
Phyla incisa																				

Table B-4. Percent frequency and cover for the 1,100-foot bitter panicum dune area.

	FOREDUNE								BAYSIDE OF DUNE											
	Foreslope				Backslope				25 ft west				125 ft west				225 ft west			
	1975		1976		1975		1976		1975		1976		1975		1976		1975		1976	
Gramineae	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover
Cynodon dactylon															3	T				
Panicum amarum			93	32	85	11	83	23	38	5	55	7	25	1	5	T			13	1
Panicum amarulum	88	22																		
Paspalum monostachyum																	3	T	3	T
Spartina patens																	5	T		
Sporobolus virginicus									8	T	3	T	23	1	15	1	5	T	18	T
Uniola paniculata	15	1	17	2	33	2	30	5	20	3	10	2	20	2	30	7	45	5	58	11
Cyperaceae																				
Cyperus esculentus																				
Eleocharis alida																				
Eleocharis caribaea											5	1			33	T			25	T
Eleocharis parvula													3	1						
Eleocharis spp.																				
Fimbristylis caroliniana													5	T			30	1		
Fimbristylis castanea									40	2	53	6	45	2	85	6	43	2	83	8
Azioaceae																				
Sesuvium portulacastrum									5	T			5	T			3	T		
Lequminosae																				
Baptisia leucophaea											3	T								
Cassia fasciculata					28	4	25	9	8	T	25	11	25	5	20	1	45	13	43	5
Euphorbiaceae																				
Croton capitatus																				
Croton punctatus			2	1			5	1	8	T	5	T	10	2			15	T		
Euphorbia ammanioides					17	1	8	1											3	T
Onagraceae																				
Oenothera drummondii					18	1	25	4	50	2	53	4	45	3	40	2	73	5	83	8
Oenothera spp.																				
Umbelliferae																				
Hydrocotyle bonariensis									5	1	20	2	5	T	25	T	20	T	18	T
Primulaceae																				
Samolus ebracteatus									3	T	13	3	13	T	23	1			28	T
Gentianaceae																				
Eustoma exaltatum									8	T			20	T	10	T	8	T	3	T
Sabatia arenicola									20	T	20	T	15	T	20	T			23	T
Convolvulaceae																				
Ipomoea pes-caprae	13	1	12	1			2	T	5	T	3	T	23	T	3	T	3	T		
Ipomoea stolonifera					7	T	21	2	28	3	43	3	5	1	3	T	13	2	8	T
Solanaceae																				
Physalis viscosa			3	T											3	T	5	T	15	1
Scrophulariaceae																				
Bacopa monnieri									5	T	5	T	10	1	10	T	8	1	13	T
Compositae																				
Erigeron myrionactis									3	T			10	1	25	2	10	T	60	3
Senecio riddellii																				
Verbenaceae																				
Phyla incisa																	3	T		

Table B-5. Percent frequency and cover for the 1,200-foot bitter panicum dune area.

	FOREDUNE								BAY SIDE OF DUNE											
	Foreslope				Backslope				25 ft west				125 ft west				225 ft west			
	1975		1976		1975		1976		1975		1976		1975		1976		1975		1976	
	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover	Freq.	Cover
Gramineae																				
Cynodon dactylon																				
Panicum amarum	100	27	100	59	98	28	98	40	48	6	48	5	3	T	5	T	3	T		
Panicum amarulum									3	2									8	T
Paspalum monostachyum																				
Spartina patens													3	T	3	T				
Sporobolus virginicus									3	T	10	1			3	T	10	T	10	T
Uniola paniculata	7	T	10	2			8	1	28	5	23	7	48	6	60	6	15	2	30	4
Cyperaceae																				
Cyperus esculentus																				
Eleocharis alida																	3	T		
Eleocharis caribaea															18	T				
Eleocharis parvula															10	T				
Eleocharis spp.																				
Fimbristylis caroliniana													35	1			63	7		
Fimbristylis castanea									18	T	58	4	8	T	50	2	30	1	33	4
Azioaceae																				
Sesuvium portulacastrum									23	T	3	T	8	T	3	T	8	T		
Leguminosae																				
Baptisia leucophaea																				
Cassia fasciculata									3	T	5	1	3	T	15	1	13	5	48	5
Euphorbiaceae																				
Croton capitatus																				
Croton punctatus									5	T			13	1	8	1	20	1	15	1
Euphorbia ammanioides																				
Onagraceae																				
Oenothera drummondii					5	T			33	2	23	1	45	3	58	5	65	6	65	7
Oenothera spp.																				
Umbelliferae																				
Hydrocotyle bonariensis											3	T								
Primulaceae																				
Samolus ebracteatus											23	T			3	T	5	T	28	3
Gentianaceae																				
Eustoma exaltatum									3	T					3	T			3	T
Sabatia arenicola					3	T			40	T	18	1	20	T	50	1	12	T	28	1
Convolvulaceae																				
Ipomoea pes-caprae	2	T							10	T	5	T	30	2	28	1	8	T	5	T
Ipomoea stolonifera									8	1	38	3	3	T	8	T	4	2	28	1
Solanaceae																				
Physalis viscosa											3	T								
Scrophulariaceae																				
Bacopa monnieri									10	T	28	1	10	T	10	T			10	T
Compositae																				
Erigeron myrionactis											13	1			8	T	8	1	30	2
Senecio riddellii																				
Verbenaceae																				
Phyla incisa																				

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TC203 .U581mr no. 77-8 627
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This study was conducted to continue monitoring foredunes formed from grass plantings during 1969 to 1973 on north Padre Island beaches. The report summarizes data obtained from elevational profiles and vegetative transects at one natural foredune and four experimental foredunes during 1975 and 1976.
1. Barrier islands. 2. Sand dune stabilization. 3. Grasses. 4. Beach erosion control. 5. Padre Island, Texas. I. Title. II. Goen, J.P., joint author. III. Series: U.S. Coastal Engineering Research Center. Miscellaneous report no. 77-8. IV. Series: U.S. Coastal Engineering Research Center. Contract No. DACW72-75-C-0011.
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